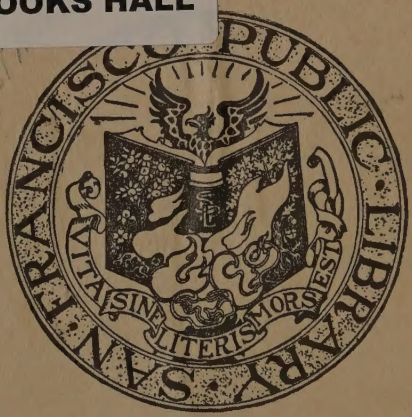
BROOKS HALL



BOOK NO. 621.33 M72 2
ACCESSION 45179
NOT TO BE TAKEN FROM THE LIBRARY
FORM NO. 37 SM-9-22

SAN FRANCISCO PUBLIC LIBRARY
3 1223 90060 8457

MODERN ELECTRIC RAILWAY PRACTICE

A Complete System of Practical Instruction in Electric Transportation

COMPLETE
IN
FOUR VOLUMES
PROFUSELY ILLUSTRATED

PUBLISHERS
W·V·WHEAT COMPANY
CHICAGO·ILLINOIS

MODERN ELECTRIC RAILWAY PRACTICE

VOLUME II

AIR BRAKE SYSTEMS ELECTRIC LOCOMOTIVES

THEIR OPERATION AND EQUIPMENT

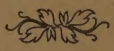
BY

CALVIN F. SWINGLE

and a Corps of Practical Electrical Experts

ILLUSTRATED

N. P. PUBLIC LIBRARY



PUBLISHERS

W. V. WHEAT COMPANY

CHICAGO

Copyright 1909
by
The National Institute of Practical Mechanics
Chicago

241

621.33 M72
4 '79

AUTHORITIES CONSULTED

SYLVANUS P. THOMPSON,
Author of Elementary Lessons in Electricity and Magnetism.

C. WALTON SWOOPE,
Author of Lessons in Practical Electricity.

HENRY S. CARHART, LL.D.,
and
HORATIO N. CHUTE, M.S.,
Authors of Physics for High School Students.

ROBERT ANDREWS MILLIKAN, Ph.D.,
and
HENRY GORDON GALE, Ph.D.,
Authors of A First Course in Physics.

FRANKLIN LEONARD POPE,
Author of Modern Practice of the Electric Telegraph.

FRANCIS B. CROCKER, E.M., Ph.D.,
Author of Electric Lighting.

AUTHORITIES CONSULTED

CLARK CARYL HASKINS,
Author of Electricity Made Simple.

HENRY C. HORSTMAN
and
VICTOR H. TOUSLEY,
Authors of Modern Wiring Diagrams and Descriptions.

L. P. DICKINSON,
Author of Easy Electrical Experiments.

FREDERICK BEDELL
and
A. C. CREHORE,
Authors of Alternating Currents.

LOUIS BELL,
Author of The Art of Illumination.

H. C. CUSHING,
Author of Standard Wiring for Electric Light and Power.

CARL HERING,
Author of Ready Reference Tables.

AUTHORITIES CONSULTED

R. W. HUTCHINSON, JR.,
Author of Long Distance Electric Power.

H. F. PARSHALL
and
H. M. HOBART,
Authors of Electric Railway Engineering.

E. PARRY,
Author of Electrical Equipment of Tramways.

F. A. C. PERRINE, A. M. D. Sc.,
Author of Conductors for Electrical Distribution.

WM. JOHN MAC QUORN RANKINE,
Late Professor of Engineering, Glasgow University.
Author of Manual of Applied Mechanics.

DR. R. H. THURSTON,
Author of Manual of the Steam Engine.

KENELM EDGCUMB,
Author of Electrical Engineers' Hand Book.

HENRY M. HOBART,
Author of Electric Motors, Their Theory and Construction.

PROF. WM. KENT,
Author of Mechanical Engineers' Reference Book.

DR. PEABODY,
Author of Manual of Steam Boilers.

PROF. WALTER S. HUTTON,
Author of Practical Engineers' Hand Book.

PROF. JAMEISON,
Author of Applied Mechanics—Mechanics of Engineering.

HENRY ADAMS,
Professor of Engineering, London College.
Author of Handbook for Mechanical Engineers.

WILFRID J. LINEHAM,
M. Inst., M. E., M. Inst., E. E.,
Author of Text Book of Mechanical Engineering.

DR. A. STODOLA
and
DR. LOUIS C. LOEWENSTEIN,
Authors of Steam Turbines, Gas Turbines, Heat Engines.

GEO. H. BABCOCK,
Ex-President American Society of Mechanical Engineers.

W. GEIPEL, M. Inst., E. E.,
M. HAMILTON KILGOUR, A. M. I. C. E., M. I. E. E.,
Authors of Pocket Book of Electrical Formulæ.

T. O'CONNOR SLOANE, A. M., E. M., Ph. D.,
Author of Arithmetic of Electricity, Standard Electrical Dictionary, Electricians' Handy Book.

WM. M. BARR,
Member American Society of Mechanical Engineers.
Author of Boilers and Furnaces—Chimneys of Brick and Metal.

C. E. KNOX, E. E.,
Member American Institute of Electrical Engineers.
Author of Electric Light Wiring.

H. A. FOSTER,
Author of Electrical Engineers' Pocket Book.

S. A. FLETCHER,
Chief Westinghouse Companies' Publishing Department.

F. H. GALE
and
MARTIN P. RICE,
General Electric Companies' Publication Bureau.

PREFACE.

The days of the hand brake, and mechanical friction brake for street and suburban electric cars have come and gone, and such appliances are now regarded by leading and experienced railway officials as being wholly inadequate to meet the demands of modern electric passenger transportation. The author has been at considerable pains therefore to collect, condense, and compile all of the latest available information bearing upon this most important subject of handling an electric car, or train of cars, safely, and at the same time economically. Beginning with a full and clearly illustrated description of the Westinghouse A. M. M. Brake equipment especially adapted to electric traction work, each of the other types of straight air, and automatic service is taken up and its construction and operation clearly explained, and plainly illustrated. This includes the National Straight Air Brake Equipment, not only for straight air, but as adapted for automatic service also; The General Electric Company's Air Brake in all of its details; The Christensen Air Brake, both straight, and automatic, is fully described and illustrated, also the Westinghouse S. M. E. equipment. Considerable space is also given to electric brakes and friction brakes.

The Electric Locomotive in all of its details is clearly described, and its construction made plain by engravings

showing every detail, also the enclosed Arc Head Light for locomotives and motor cars.

A set of questions and answers, or catechism, follows immediately after each subject has been discussed, thus enabling the student to firmly grasp and retain in his mind the pith of the matter studied.

H.

THE AIR BRAKE IN ELECTRIC RAILROADING.

It is not exaggeration to say that no other invention in steam or electric railway engineering has contributed so largely to the safe operation of high speed cars as has the power or air brake in its present improved form. The hand brake and mechanical friction brake have come and gone, being now regarded by all well-informed and experienced railway officials as wholly inadequate to the demands of modern electric railway operation.

Motormen and conductors of electric cars should possess something more than a mere knowledge of how to apply and release brakes. They should understand the mechanical principles represented in the brake, and should know how to detect, remedy, and report any, and all kinds of defects which may arise.

The cars operated in interurban service are not only very heavy, but the speed at which they travel is in many cases faster than ordinary steam railroad cars. Many steam railroads feel that they are doing very well if their freight schedules average twenty-five miles an hour, whereas nearly all interurban electric railways make an average schedule of at least thirty miles an hour. Such being the case, it is highly important that motormen and conductors master as fully as possible all detailed knowledge of the operation and maintenance of the brake apparatus.

An earnest effort has been made by the author to place before the student in the following pages a plain, yet comprehensive description of the several systems of air brakes as applied to electric cars and locomotives.

This will include in detail the very latest and most modern apparatus. The principles of its construction and action are set forth in plain language, and correct methods of operating the different systems are explained in such a manner as to be easily understood.

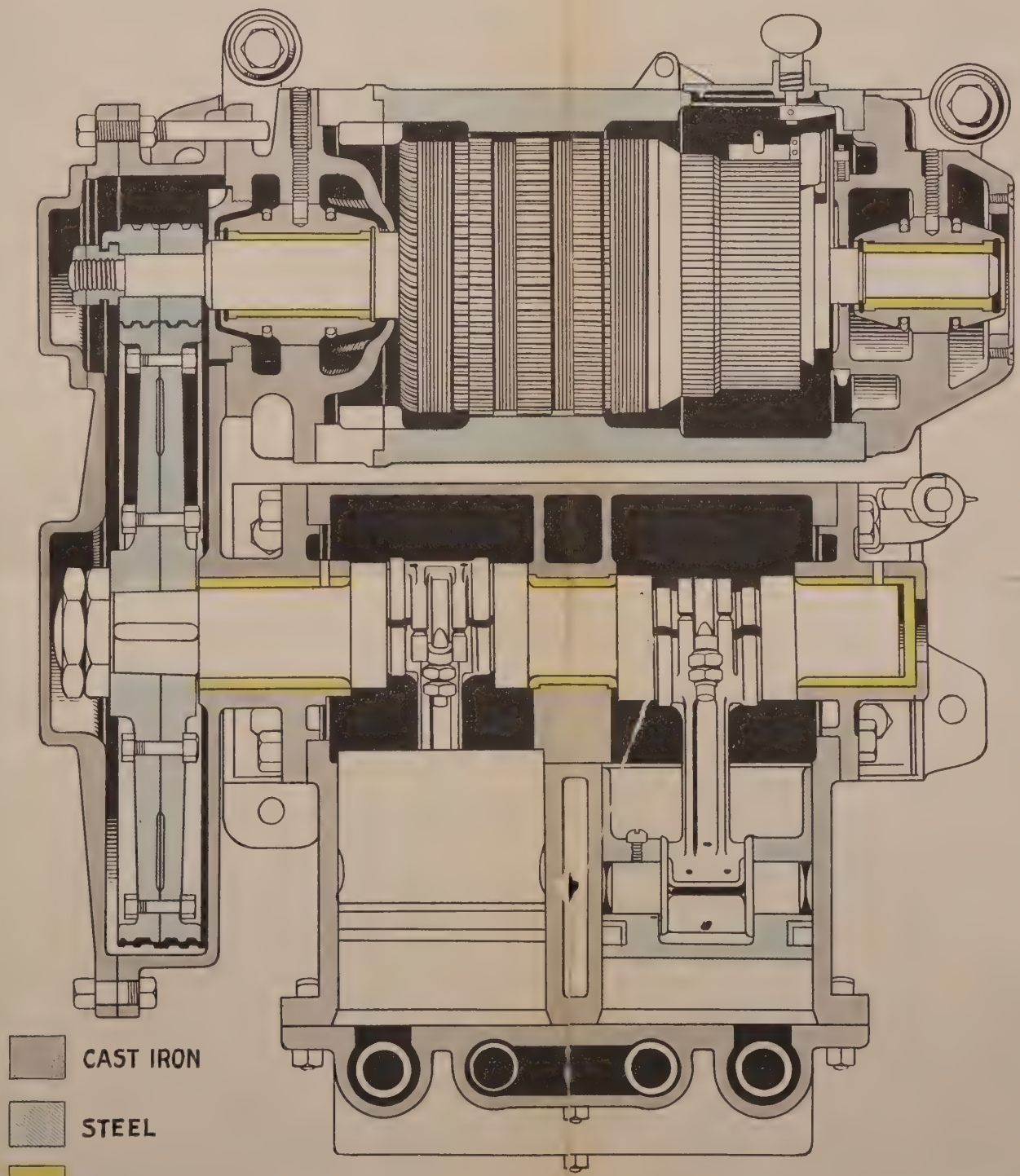
THE WESTINGHOUSE AMM BRAKE EQUIPMENT.

This equipment is designed for use on electrically operated vehicles, running normally in trains up to five cars in length, but subject to single car operation at times. It is therefore more especially adapted for both city and high-speed interurban train service, and possesses certain marked advantages, some of which may be enumerated as follows:

1st. It is a strictly *automatic* brake system; that is, any reduction in brake pipe pressure, which may result from a rupture of the piping, burst hose, or parting of the train, will cause the brakes to apply with full power. This is the essential feature which distinguishes the automatic from the straight air types of brake apparatus, and to which all other operative advantages are subordinate in the safe and economical handling of the trains of today.

2d. It possesses the *quick-recharge* feature, by which a rapid recharging of the auxiliary reservoirs is secured, thus insuring the possibility of obtaining full braking power immediately after a release has been made, and permitting as many applications and releases in quick succession as may be desired, without depleting the system.

3d. It possesses the *quick-service* feature, which se-



TOP VIEW OF MOTOR AND COMPRESSOR IN SECTION

WESTINGHOUSE AIR COMPRESSOR

cures a very quick serial action of the brakes throughout the train in service applications, similar in character to that obtained in an emergency application, but less in degree. This makes certain the prompt and uniform application of all brakes in the train during service operation, and increases correspondingly the effectiveness of any given brake pipe reduction.

4th. It has the *graduated release* feature (at the triple valve), which enables the motorman to control the exhaust of brake cylinder pressure at will and thus partially or entirely release the brakes on the entire train as may be desirable. This permits him to apply the brakes with maximum power at the beginning of the stop and release in a series of steps or graduations as the speed diminishes, thus accommodating the brake shoe pressure to the reduction in speed, allowing the trucks to right themselves, and combining smoothness with accuracy, and shortness of stop to much greater degree than is possible under ordinary conditions where this feature does not exist.

5th. In addition to the preceding, by simply running an extra pipe from the triple valve exhaust to the brake valve it is possible to obtain a *straight-air release,* when desired, on the leading or operating car. By means of this the brake cylinder exhaust on the leading car only of a train, or on any motor car operating singly, can be controlled *at the brake valve,* and the brakes on that car graduated off exactly as in straight-air operation. This is of great advantage where single-car operation is frequent or where service conditions require it.

6th. It has high-pressure emergency. This feature insures maximum brake-cylinder pressure in emergency applications, thus giving the shortest possible stop when it is most needed.

OPERATING PARTS.

The diagram, Fig. 1, shows, in a clear and easily understood manner, the general arrangement of the operating parts of a motor car fitted with the AMM equipment, and the following is a short description of each one of the parts:

1. A *motor-driven air compressor,* which furnishes the compressed air for use in the brake system.

2. An *electric pump governor,* which automatically controls the operation of the compressor between predetermined minimum and maximum pressures.

3. A *fuse box, fuse,* and two *snap switches,* in the line from the trolley to the governor and air compressor, protecting the latter from any excessive flow of current and enabling the current supply to the compressor to be entirely cut off when desired.

4. Two *main reservoirs,* to which the compressed air is delivered from the air compressor, where it is cooled and stored for use in charging the brake system. Where climatic conditions render it necessary, radiating pipe should be installed between the compressor and the first reservoir, and between the two reservoirs, to assist in the cooling process.

5. A *safety valve* connected to the main reservoir pipe, which protects against excessive main reservoir pressure.

6. A *feed valve,* which automatically maintains a predetermined normal pressure in the brake system.

7. A *duplex air gauge* connected to the piping near each brake valve, which shows by a red hand the pressure in the main reservoirs, and by a black hand the pressure in the brake pipe.

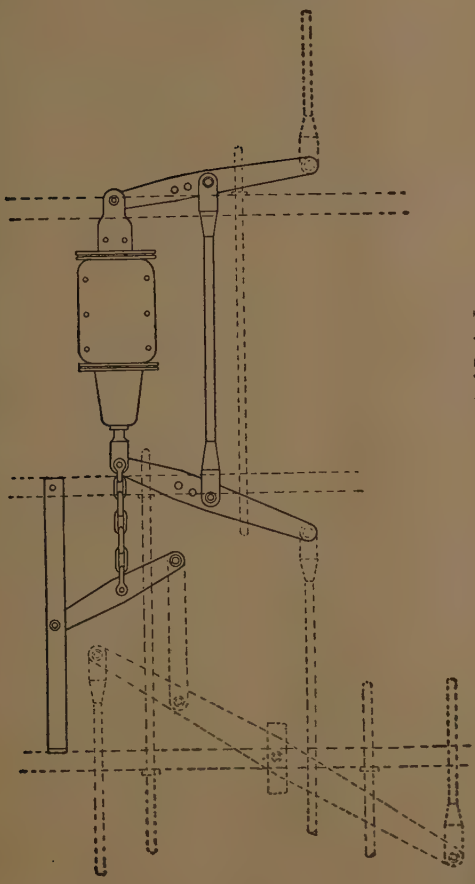


Diagram Showing Arrangement of Brake Levers.

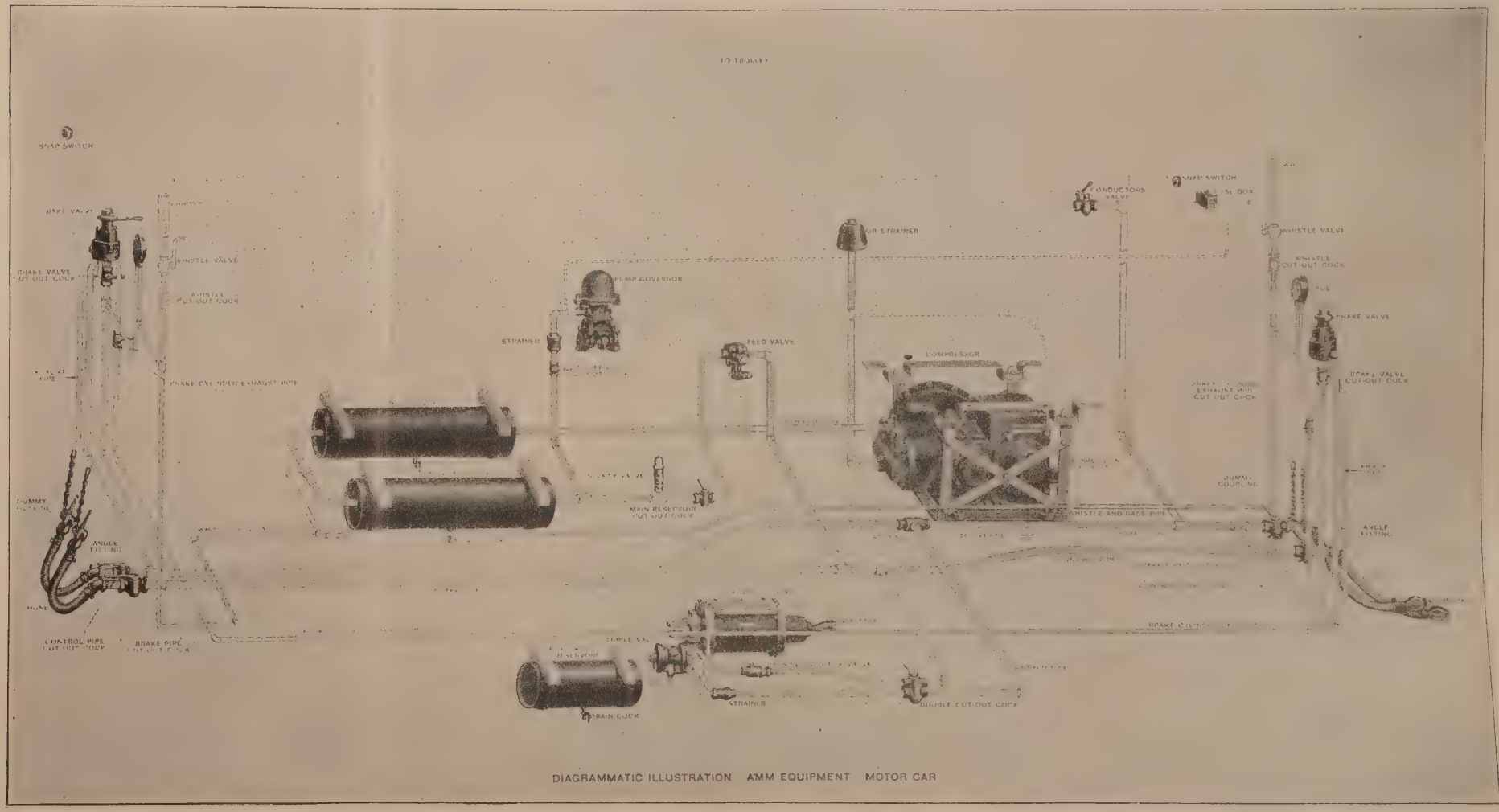
8. Two *brake valves,* one at each end of the car, through which *(a)* the air supplied by the feed valve is allowed to enter the brake pipe for the purpose of releasing the brakes and recharging the system; *(b)* the air in the brake pipe is allowed to escape to the atmosphere when applying the brakes; *(c)* the flow of air to or from the brake system may be prevented as when the brakes are being held applied; *(d)* the air in the brake cylinder is allowed to flow directly to the atmosphere ("Straight-Air Release"), on equipments where the brake cylinder exhaust is piped to the brake valve.

9. A *triple valve,* which has connections through the brake cylinder head (or pipe bracket if used) to the brake pipe branch pipe, the control pipe branch pipe, and the auxiliary reservoir, brake cylinder and exhaust pipes. It operates automatically in response to an increase or decrease in brake pipe pressure, so as to (*a*) charge the auxiliary reservoir, by opening communication to it from the brake and control pipes, *(b)* apply the brakes, by allowing the compressed air stored in the auxiliary reservoir to flow into the brake cylinder, *(c)* release the brakes, by allowing the air in the brake cylinder to escape to the atmosphere.

10. An *auxiliary reservoir,* in which is stored the air supply for operating the brakes on the car.

11. A *brake cylinder,* with a piston and rod so connected through the brake levers and rods to the brake shoes, that when the piston is forced outward by air pressure this force is transmitted through said rods and levers to the brake shoes and applies them to the wheels.

12. A *conductor's valve,* located inside each car, enabling the conductor or guard to apply the brakes if necessary.



DIAGRAMMATIC ILLUSTRATION AMM EQUIPMENT MOTOR CAR

Fig. 1.

13. Various *cut out cocks, air strainers, check valves, hose, couplings, dummy couplings*, etc., the location and uses of which will be readily understood from the diagrams Figures 1 and 2.

14. Two *air alarm whistles*, one at each end of the car, with whistle valves and cut out cocks.

Figure 2 shows in a graphic manner the equipment of a trailer car, and is self-explanatory. In operative features a trailer car corresponds exactly to any motor car equipped with this device, with the exception of the leading, or operating feature. It differs from a motor car in that it has no brake valves, alarm whistle, or motor compressor, governor, or main reservoir. It draws its supply of air from the motor cars in the train, through the brake, and control pipes.

THE TYPE M TRIPLE VALVE.

In city service requiring its frequent stops, and maximum of flexibility demanded of a brake equipment, as compared with the interurban or long-distance runs between cities, there are two extremes of service required of the air brake equipment. For instance, the city service requires a moderate brake cylinder pressure, for moderate brake pipe reductions, and the ability to graduate the release, as well as the application of the brake, while for a high speed service between towns, a high emergency pressure is essential when the shortest possible stop is demanded.

M TRIPLE VALVE.

In order to meet these requirements, the Westinghouse Traction Brake Company has developed the Type M

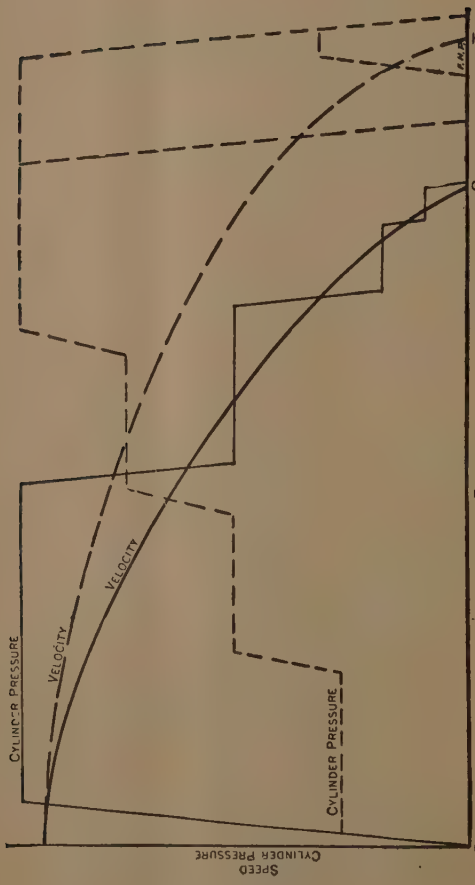


Diagram of Stops.

Fig. 2.

triple valve, especially adapted to the particular kind of service described. This triple valve forms a part of the AMM equipment, which is designed throughout to meet the service conditions outlined above.

Figure 3 shows a full view of this valve, and Figure 4 gives end and side sectional illustrations showing the working parts, the names of which are as follows:

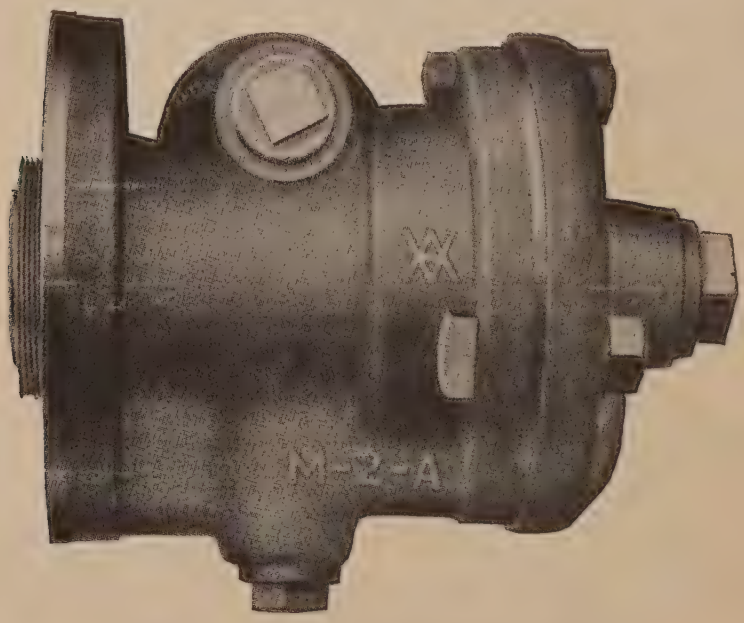


Fig. 3. The Type "M" Triple Valve.

2, Valve Body; 3, Slide Valve; 4, Piston; 5, Piston Ring; 6, Slide-Valve Spring; 7, Graduating Valve; 8, Graduating-Valve Spring; 9, Check Valve; 10, Rubber Seat or Check Valve; 11, Check-Valve Spring; 12, Cap Nut or Check Valve; 13, By-Pass Piston; 14, By-Pass Piston Ring; 15, Cap Nut for By-Pass Piston; 16, By-Pass Valve; 17, Rubber Seat for By-Pass Valve; 18, Cap Nut for By-Pass Valve; 19, By-Pass Valve Spring; 20, Cylinder Cap; 21, Graduating Nut; 22, Graduating

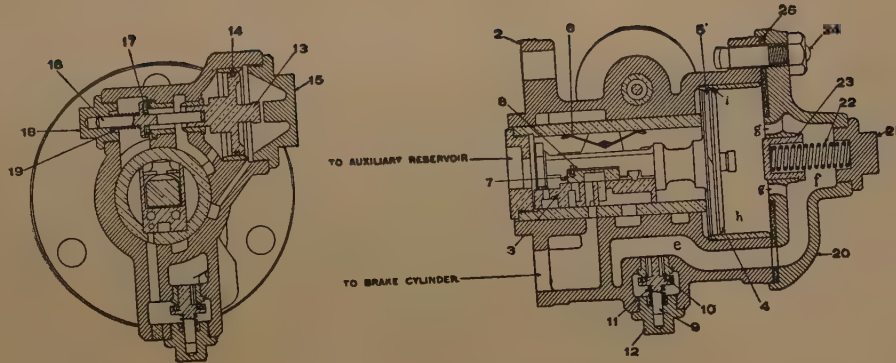


Fig. 4. The Type "M" Triple Valve.—Sectional Views.

Spring; 23, Graduating Sleeve; 24, Bolt and Nut; 25, Cylinder Cap Gasket.

Fig. 5 illustrates the actual arrangement of ports and cavities in the graduating valve, slide valve and slide-valve seat of the M-2-A Triple Valve. From Fig. 5 it can be easily seen that it is impossible to show all the ports and connecting passageways in the slide valve, graduating valve and seat by any single section taken through the valve. Figs. 6, 7, 8, 9, 10 and 11 have therefore been made to show in a purely diagrammatic way the relations of the various ports to each other, for the different positions of the triple-valve piston. The actual proportions and the mechanical construction of the parts have been entirely disregarded in order to make the connections and operation more easily understood. The pipe connections to the triple valve are plainly marked at the side of the cuts, Figs. 6 to 11 inclusive.

The letters designating the ports and passageways, appearing on Figs. 4 and 5 and Figs. 6 to 11 inclusive, correspond throughout. By comparing these diagrammatic views and the explanations given with Figs. 4 and 5, the various connections and the relations of the different ports will be clear.

Referring to the plan of the slide-valve seat, Fig. 5, the ports are as follows: r leads to the brake cylinder, t to the top of the by-pass piston, p to the exhaust, x to the control pipe, and y to the check valve 9 in the passageway leading from the brake-pipe connection. The registration of the ports in the slide valve, graduating valve and slide-valve seat is most easily followed and understood by reference to and comparison with the diagrammatic drawings, Figs. 6 to 11 inclusive, and the explanations given for each.

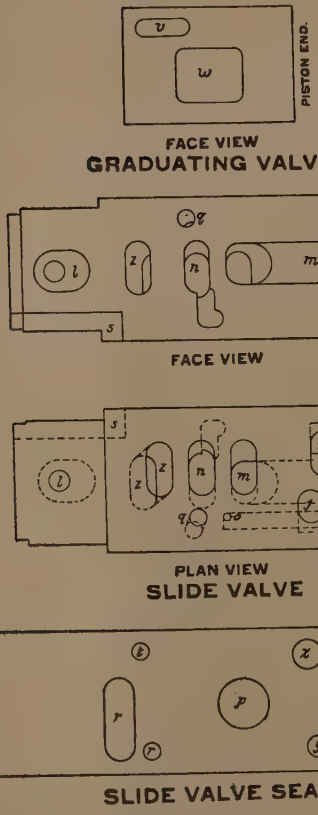


Fig. 5. Type "M" Triple Valve.—Graduating Valve, Slide Valve, and Slide-Valve Seat.

OPERATION OF THE TYPE "M" TRIPLE VALVE.

Charging. Referring to Figs. 5 and 6, air from the brake pipe enters the triple valve through the passages *a*, *e*, *g* and *h* to the face of the triple-valve piston (which is then forced to Release Position as shown) thence through the feed groove *i* to the chamber above the slide valve and to the auxiliary reservoir. Brake pipe air in passage *a* also forces the check valve 9 from its seat and flows thence through the ports *y*, *j* and *u* into the auxiliary reservoir.

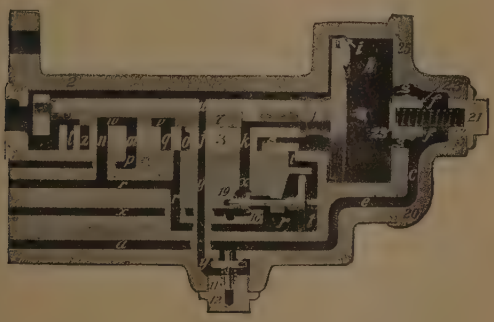


Fig. 6. Release and Charging Position.

At the same time air from the control pipe, entering the triple valve through passage *x*, flows through port *k* into the chamber above the slide valve and to the auxiliary reservoir. The latter is thus recharged from two different sources through three different channels, and full auxiliary reservoir pressure can be restored after an application in a very short time. The rate at which

this takes place is such that the rise of auxiliary reservoir pressure is proportional to the fall of pressure in the brake cylinder, so that by the time the brake is fully released, the reservoir is practically fully recharged. The check valve 9 prevents the air in the auxiliary reservoir from flowing back into passage *a*, and the brake pipe when, for any reason, the pressure in the latter becomes lower than that in the reservoir.

When in this position, air from the brake cylinder entering the triple valve through passage *r*, flows through ports *n*, *w*, *m* and *p* to the exhaust, thus releasing the brakes.

Service Application. The parts of the triple valve being in Release and Charging Position as shown in Fig. 6, a service reduction in brake-pipe pressure reduces the pressure in chamber *h* and on the face of the triple valve piston below that remaining in the auxiliary reservoir on the opposite side of the piston. The higher auxiliary-reservoir pressure therefore forces the piston in the direction of the lower brake-pipe pressure, carrying with it the attached graduating valve. The first movement of the piston cuts off the feed groove *i* and the graduating valve, then closes the ports *n*, *j* and *k*, thus closing communication between the brake pipe and the auxiliary reservoir, the control pipe and the auxiliary reservoir, and the exhaust from the brake cylinder to the atmosphere. The same movement uncovers port *z* and connects ports *q* and *o*, in the main slide valve, through cavity *v* in the graduating valve. The spider on the end of the piston stem then engages the end of the slide valve, which is carried along with the piston and graduating valve as the reduction continues. This brings the parts into Quick-Service Position shown in Fig. 7. Serv-

ice port z in the slide valve registers with the brake-cylinder port r in the seat, permitting the air in the auxiliary reservoir to flow to the brake cylinder and apply the brakes. At the same time the quick-service ports o and q and cavity v connect passage y, above the check valve 9, with passage r leading to the brake cylinder, thus allowing air from the brake pipe to lift the check valve and flow through the above named ports to the

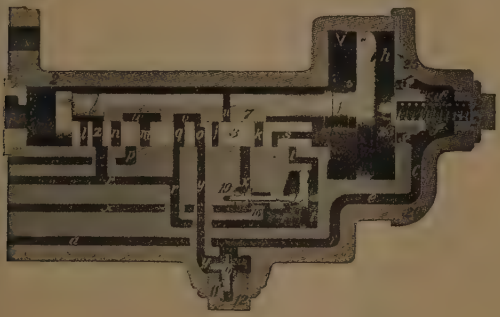


Fig. 7. Quick-Service Position.

brake cylinder. This constitutes the Quick-Service action of the triple valve, in that it causes a slight but definite reduction in brake-pipe pressure locally at each triple valve, which quickly and uniformly transmits from car to car throughout the train the effect of a reduction in brake-pipe pressure made at the brake valve. This is not great in amount; first, because the ports and passageways are small; and, second, because in the movement of the slide valve 3 toward Full-Service Position the quick-service port q is restricted as it approaches this position, and completely closed just before the serv-

ice port z is fully open. The amount by which the service port is opened in any given case depends on the rate of reduction in brake-pipe pressure as compared with that of the auxiliary reservoir. If the former is at first rapid as compared with the latter (which would be the case with short trains) the higher auxiliary-reservoir pressure moves the piston at once to Full-Service Position, Fig. 8, thus automatically cutting out the quick-service feature where it is not needed. When in Full-

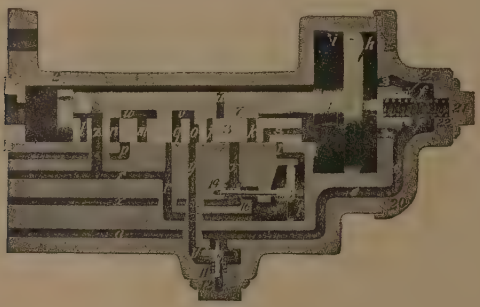


Fig. 8. Full-Service Position.

Service Position, Fig. 8, the service port z is fully open and the quick-service port q is closed. This stops the flow of air from the brake pipe to the cylinder and the quick-service action ceases. As shown in the cut, the graduating spring is compressed slightly when the piston is in Full-Service Position.

Lap. After a sufficient brake-pipe reduction has been made to produce the desired application of the brakes, the brake-valve handle is lapped, and further escape of air from the brake pipe is prevented. This position is

called service lap, and is shown in figure 9, all of the ports being blanked by the graduating valve, and further flow of air to the brake cylinder is stopped. During lap position the main slide valve remains in service position, a movement of the piston and graduating valve serving to lap the valve, while a very slight reduction in brake pipe pressure will again bring the piston and graduating valve into service position. While the piston 4 (see Fig. 9) is in service lap position, the pressure on both sides

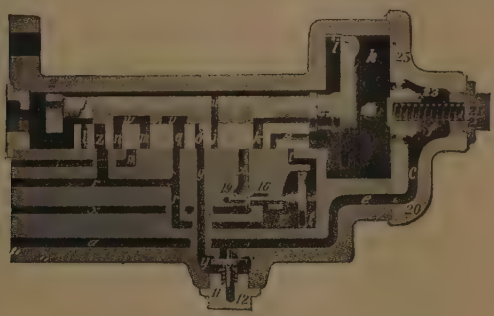


Fig. 9. Service-Lap Position.

of it must be equal. If now the brake pipe pressure is increased in order to release the brakes, the higher pressure on that side of the piston will cause it to move the graduating and slide valves to the extreme left, to release and recharging position (see Fig. 6), and the brake cylinder air is exhausted through ports *r* and *n*, cavity *w* and port *m* to exhaust passage *p* and atmosphere, while at the same time the auxiliary reservoir is being recharged through charging ports *x* and *y* and feed groove *i*, as described under the head of charging.

Graduated Release. If, however, after the brakes have been applied, the reduction previously made in the brake pipe is only partially restored, and only sufficient air is permitted to flow into the brake pipe to move piston 4, with the slide and graduating valves, to Release Position, Fig. 6, and the brake-valve handle is then returned to Lap Position, the flow of air from the control pipe through ports x and k to the auxiliary reservoir continues after the rise in brake-pipe pressure has ceased. This will raise the pressure on the auxiliary-reservoir side of

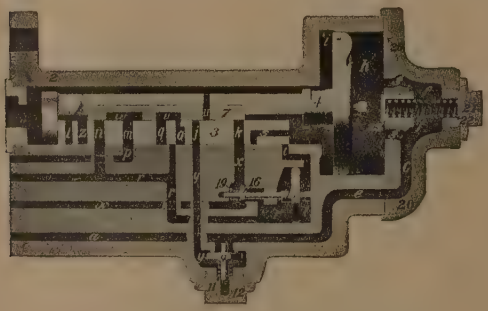


Fig. 10. Graduated-Release-Lap Position.

the triple-valve piston slightly above that on the brake-pipe side, and cause the piston and its attached graduating valve to move to the right to Graduated-Release-Lap Position shown in Fig. 10.

Emergency. When the brake-pipe pressure is reduced suddenly, or its reduction continues to be more rapid than that in the auxiliary reservoir, the triple-valve piston moves to the extreme right, compressing the gradu-

ating spring and bringing the parts into Emergency Position as shown in Fig. 11. In this position air from the auxiliary reservoir enters the brake-cylinder passage *r* through the port *l* in the main slide valve instead of port *z* as in service application. At the same time port *s* in the main slide valve registers with port *t* in the seat, thus permitting air from the auxiliary reservoir to flow to the face of the "By-Pass" piston 13, the other side of which is connected to the brake cylinder through port *r*. As there is no pressure in the brake cylinder at this

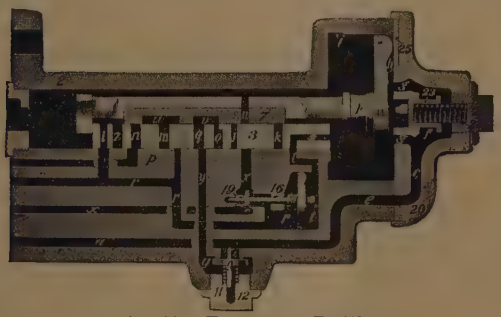


Fig. 11. Emergency Position.

instant, the by-pass piston with its attached by-pass valve 16 is forced to the left, as shown in Fig. 11, thus opening a passageway between the control-pipe connection *x* and the brake-cylinder connection *r* through the by-pass valve. Air continues to flow from the control pipe to the brake cylinder through this channel until the auxiliary reservoir and brake-cylinder pressures become nearly equal. Then the by-pass piston and valve are returned to their normal positions by the valve spring 19, and the flow of air through the by-pass valve is stopped.

TRAILER CAR.

The equipment of a trailer car consists of an auxiliary reservoir, brake cylinder, triple valve, double cut out, combined check valve and strainer, conductor's valve, brake and control pipes and the accompanying fittings, as shown in Fig. 1. In operative features, therefore, a trailer car corresponds to any motor car, except the leading or operating one. It differs from a motor car in having no brake valves, alarm whistle, or motor compressor, governor, or main reservoir, its supply of air being drawn from the motor cars in the train.

ARRANGEMENT OF APPARATUS.

In deciding upon the best location for the compressor, radiating pipe, reservoirs, brake cylinder, etc., due regard must be had for the distribution of electrical apparatus under the car, the most efficient arrangement of foundation brake gear possible, maximum cooling effect, and accessibility of all apparatus for inspection. As proper maintenance is of the utmost importance in obtaining all the advantages possible with this equipment and in prolonging its life, this latter point should receive special attention.

Place the *air compressor*, Fig. 12, near the side of the car. The gear case should face outward, if the inspections are made over a pit, to afford easy access to the commutator, brush holders, and oil cups. If the inspections are to be made from the side of the car the gear

case should face inward. The suction strainer is connected by piping with the air inlet. It should be so located as to insure a supply of clean, dry, cool air, which adds materially to the life and efficiency of the compressor. Usually this strainer is installed, either in one of the cabs, or on the roof. When the air compressor is operating, the air is drawn into the cylinders through the suction strainer, and past the inlet valves, compressed, and forced out past the discharge valves and through radiating pipe to the *main reservoirs*. As shown

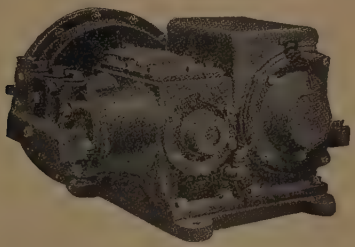


Fig. 12. Motor-Driven Compressor. Type D. Form EG.

in Fig. 1, two main reservoirs are used, for the purpose of storing an abundant supply of compressed air to permit of promptly releasing the brakes and recharging the system. The division of the storage volume into two reservoirs also gives a more efficient arrangement for cooling the air and depositing the moisture, oil, or other foreign matter carried into the reservoirs, before passing on to the brake system. To assist in this the piping should be so installed as to drain into the reservoirs. The *drain cocks* should permit of easily draining the reservoirs. As an accumulation of water or other foreign matter is not only injurious to the reservoirs, but is

liable to seriously reduce their capacity, they should be drained at regular intervals.

The amount of radiating pipe necessary must be decided upon according to the needs of each locality. Where it is always warm, it may be omitted. For obvious reasons, the reservoirs and radiating pipe should be placed as low and as near the outside of the car as possible and well removed from sources of heat, such as resistance grids, motors, etc. As indicated on the diagram, the main reservoirs are directly connected to the governor, feed valve, duplex air gauges, and alarm whistles.

Fig. 13. Electric-Pump Governor. Type J.

A *cut-out cock* and an *air strainer* are placed in the governor pipe—the former to cut off the supply of air to the governor when it is necessary, and the latter to protect the governor from dirt or foreign matter which may enter the pipe.

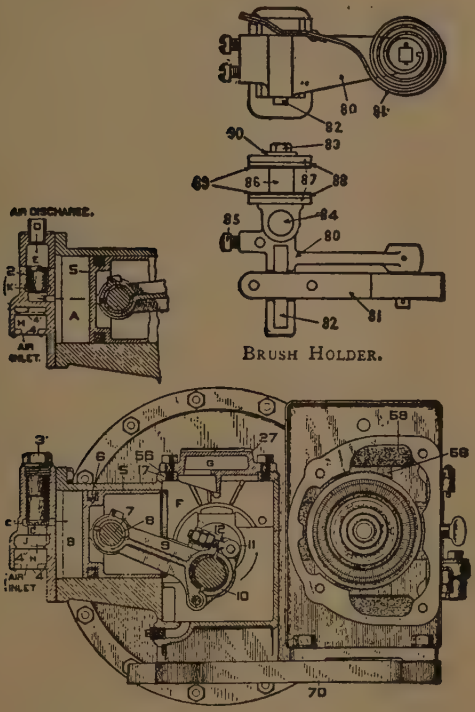


Fig. 14. Air Compressor on Motor Cars.

The air strainer should be placed as near the governor as possible. Figures 14 and 15 show, respectively, side and sectional views of the air compressor.

The *electric pump governor*, Figs. 13 and 18, is usually set for a 15-lb. range, the actual pressures being de-

termined by the operating conditions of each particular road. The standard and recommended cutting-in pressure is 85 lbs. (15 lbs. above the setting of the feed valve) and the cutting-out pressure 100 lbs.

In the circuit between the trolley and governor are placed two *snap switches*, Fig. 16, and a *fuse box* with *fuse*, Fig. 17. The snap switch affords a means of cutting off the current to the air compressor when so desired; while the fuse serves to protect the motor from a dangerous continued overload by blowing, and thus opening the circuit, when the amount of current flowing to the compressor exceeds the capacity of the fuse.

INSTALLATION OF WIRING.

The *wiring* should be installed in a thorough manner, every precaution being taken to avoid the possibility of grounds developing after the car has been in service for a time. Whenever practicable, the wiring should be run inside the car, securely cleated in place, and must always be so located that it may not be damaged when the body is being jacked up. At exposed places underneath the car, and particularly at those points where the wire comes in contact with iron, it must be covered with rubber tubing. The size of rubber insulated wire which is recommended for the Nos. 1, 2 and 3 compressors when operating on standard railway voltage is No. 14 B. & S. gage. Although smaller sizes might do the work without excessive drop in voltage or danger of overheating, still they lack mechanical strength and a smaller wire than No. 14 is undesirable on this account. Under these conditions the No. 4 compressor should be wired with No. 12 B. & S. gage.

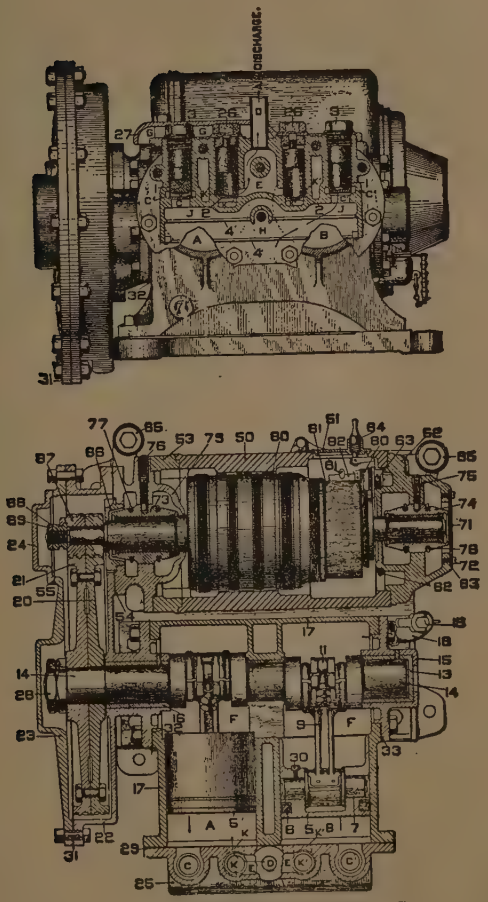


Fig. 15. Air Compressor on Motor Cars.

The sequence in which the various parts should be connected is shown in Fig. 1, but the point at which the compressor circuit shall be tapped to the main trolley line is one to be determined in each individual case. Connecting inside the main motor choke is not advisable, for, although the apparatus of the compressor circuit will be protected by the lightning arrester on the car motor circuit, there are many drawbacks to this method. By tapping on the trolley line outside the main switches we overcome all disadvantages, and if the connection is made between the first main switch and the

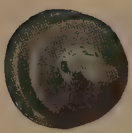


Fig. 16. Snap Switch.

Fig. 17. Fuse Box.

point where the light circuit is tapped off, *and the lamp circuits are turned on during storms,* a very efficient lightning arrester is provided. The better plan, of course, is to provide a separate arrester for the compressor circuit, which involves only a slight additional expense. From the trolley connections, run the wire first to one compressor switch, and then to the other, connecting them in series, and making sure that when they are open their dials show the word "off," and when

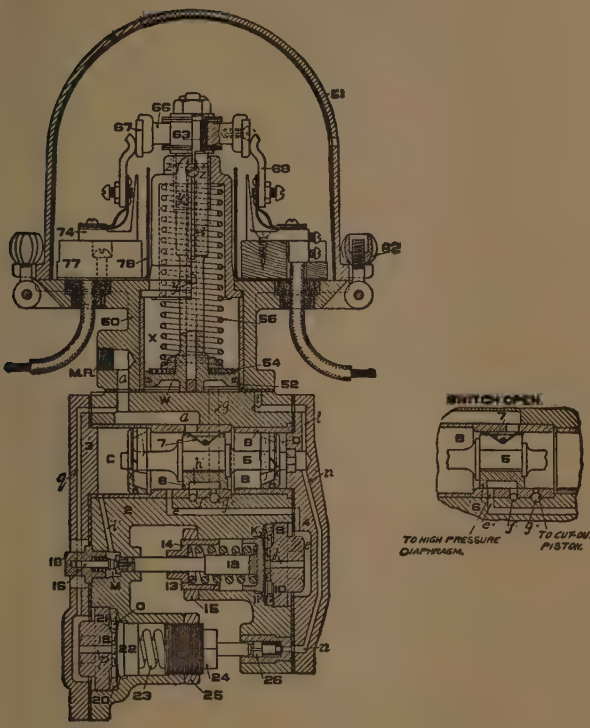


Fig. 18. Air Compressor Governor on Motor Cars.

closed, "on." From thence run the wire through the fuse box to the governor, where the connection may be made to whichever terminal is most convenient. From the remaining terminal run a wire to the motor, where the connection must be made to the field lead which

comes out of the frame near the door. The armature lead must be connected to the main motor ground wire. By this means a grounded field coil, or lead can cause no damage to the armature. The positive wire leading to the motor, and the ground return from the same should, under no circumstances, pass through the same hole, or be cleated together, but should be kept three or more inches apart. The compressor switches, one at each end, should be located within easy reach of the motorman, without necessitating his moving from his customary position. The fuse box should be connected between the last compressor switch and the governor. It ought not to be so placed that a screwdriver or other implement is needed to get at it, but should be easily accessible, in a dry place, with its box well removed from any possible ground connections. The safety valve, Fig. 19, is connected by a tee to the main reservoir pipe, in as protected a location as possible, and is set for 110 lbs., or 10 lbs. above the cutting-out point of the governor. In the main reservoir pipe beyond the safety valve, and governor connection, is placed a cut-out cock for the purpose of shutting off the source of air supply on that car when desirable. The feed valve, Fig. 20, is usually set to maintain a standard pressure of 70 lbs. for braking purposes, but this may be varied as operating conditions require, the governor adjustment being then changed accordingly. It should be located as near as possible to the point where the branch is taken from the control pipe to the triple valve. The feed valve is bolted to a pipe bracket (which should be firmly attached to a solid support), thus avoiding the necessity of breaking any pipe joints when removing the valve for cleaning. An arrow cast on the top of this bracket indicates

the direction in which the air should flow through the valve. Both the feed valve and pump governor should be installed inside the car where the best protection from dirt and weather will be afforded, and where they can be easily reached for adjustment or replacement.

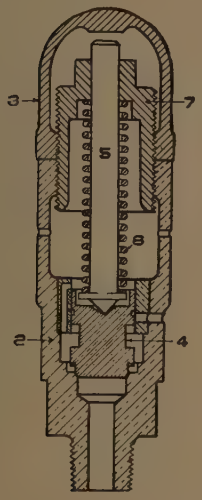


Fig. 19. Safety Valve.

Fig. 20. Feed Valve.

The *control pipe*, extending the entire length of the train, is supplied from the feed valves on each motor car. Each individual feed valve, therefore, supplies its proper proportion of the air required to recharge the control pipe when the pressure has been reduced by a release of the brakes. In this way each air compressor is made to do an equal share of the work necessary to

supply the air required for operation, without the need of additional apparatus of any kind to secure this essential feature. Also, if any compressor fails, the work of supplying the air is divided among the remaining com-

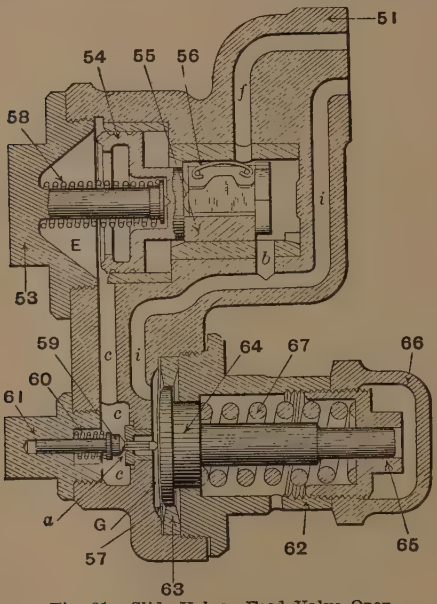


Fig. 21. Slide Valve—Feed Valve Open.

pressors. Flexible hose and couplings at each end of the car serve to connect this pipe throughout the train.

From this pipe a branch leads to each triple valve, and one to the brake valves on each car. The supply to the triple valve is used to obtain a graduated release

of the brakes and assist in the recharging of the auxiliary reservoirs, and the supply to the brake valve enables the motorman to release the brakes and assist in recharging the system. Figs. 21 and 22 are sectional views of the

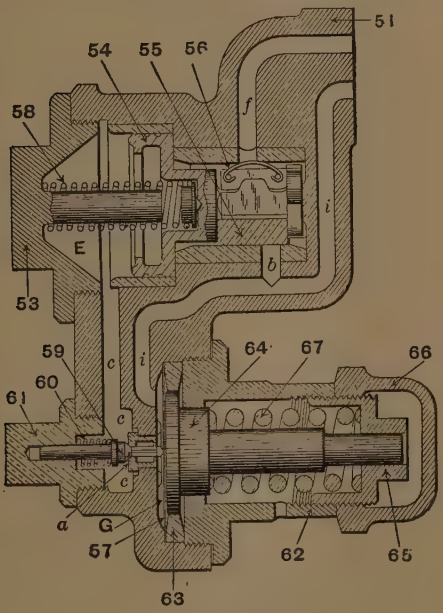


Fig. 22. Slide Valve—Feed Valve Closed.

feed valve, showing it in the open and closed positions, respectively.

The *duplex air gauge*, Fig. 24, should be installed in the direct line of vision of the motorman while running

over the road, and where it is not obscured in any way by intervening objects, or too strong light back of, or near it. The connection for the brake pipe gauge hand is taken off from the brake pipe just below the brake valve cut-out cock.

The alarm whistle valve should be within easy reach of the motorman, while operating the controller handle. The alarm whistle, whistle valve, and whistle cut-out cock are connected through the gauge and whistle pipe

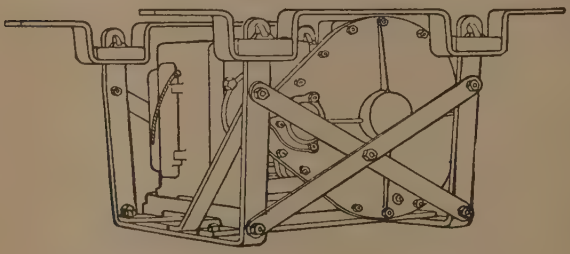


Fig. 23. Suspension Cradle of Air Compressor.

directly to the main reservoir pipe. The connection should be made between the two reservoirs in order to avoid any possibility of interfering with the operation of the other devices when blowing the whistle. The connection for the main reservoir gauge hand is taken out from this pipe just below the cut-out cock. A choke in the gauge pipe protects the gauge from injury due to the sudden drop in pressure in the pipe when the whistle is blown.

The *brake valve*, Fig. 25, located in the operator's compartment at each end of a motor car, is of the rotary type, with removable handles. The operating parts are

contained in a body, mounted on a bracket to which all the pipe connections are made, so that the valve may be removed for examination and repairs without breaking any pipe joints.

Four pipe connections are made to the bracket as follows: the control pipe (supply pipe), brake pipe, brake cylinder exhaust pipe, and brake valve exhaust pipe. Raised letters are cast on the bottom of the pipe bracket, Fig. 26, as follows, to insure that proper connections are made: S, for control pipe; BP, for the brake pipe; BC-EX, brake cylinder exhaust pipe; and EX, brake valve exhaust pipe.

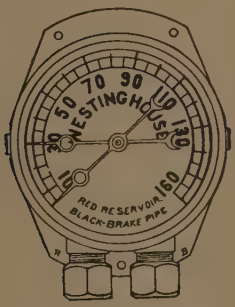


Fig. 24. Duplex Air Gauge.

The different positions of the brake valve handle in order from the left (see Fig. 27) are:

1st. Release and Running Position (at the extreme left), in which the air from the control pipe, which always has access to the top of the rotary valve through a port in the body casting, is permitted to flow directly to the brake pipe, and the brake cylinder exhaust is connected to the atmosphere.

2nd. Holding Position, in which air from the control pipe still flows into the brake pipe, but the brake cylinder exhaust is prevented from flowing to the atmosphere.

3rd. Lap Position, in which all ports in the valve are blanked, except the brake cylinder exhaust port. This is the only position in which the brake valve han-

Fig. 25. Brake Valve. Type M15.

dle can be removed. On all motor cars back of the head car, the brake valves are in lap position. Consequently the brake cylinder exhaust port must be open in this position, in order to permit the release of the brakes on such cars.

4th. Intermediate Service Position, in which a connection is made from the brake pipe to the atmosphere through a relatively small opening, thus allowing the

air in the brake pipe to escape to the atmosphere at a comparatively slow rate.

5th. Service Position, in which a connection is made from the brake pipe to the atmosphere through a larger opening than in the intermediate service position, thus allowing the air in the brake pipe to escape at a more rapid rate.

6th. Emergency Position, in which a much larger opening is made from the brake cylinder to the atmosphere.

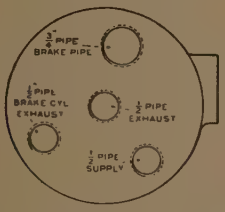


Fig. 26. Brake Valve Pipe Bracket.

From the brake valve the brake pipe extends throughout the train, similar to the control pipe, having flexible hose and couplings to form the connection between the cars. Branch pipes lead from the brake pipe to the brake valve, conductor's valve, and the triple valve connection on the brake cylinder head. When the brakes are released, the pressure in this pipe is the same as that in the control pipe—they being then connected through the operating brake valve.

The *conductor's valve,* one type of which is shown in Fig. 28, may be located at any convenient point in the car, preferably with a cord attached to its handle and

opened, the air in the brake pipe flows directly through it to the atmosphere, setting the brakes in emergency. It should therefore be used only in case of actual danger, and should then be opened as wide as possible and held open until the train stops.

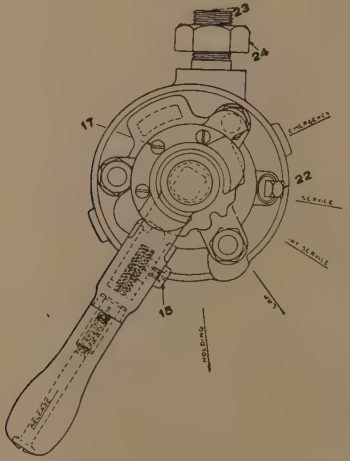


Fig. 27. Brake Valve. Plan View.

The connection from the brake pipe to its branch pipe, leading to the triple valve, is made through a *brake pipe air strainer*, Fig. 29, to prevent the entrance of foreign matter into the triple valve. For further protection, a *branch pipe air strainer*, Fig. 30, is inserted in the branch pipe close to the triple valve connection on the brake cylinder head or bracket.

The alarm whistle valve should be within easy reach of the motorman while operating the controller handle.

Near the triple valve is a double cut-out cock, Fig. 31, through which the branch pipes from the brake and control pipes pass. This is similar to an ordinary cut-out cock, except that it has two separate passages through both body and key, the upper one for the ⅜-inch control branch pipe, and the lower one for the 1-inch brake pipe branch pipe. By this arrangement both passages are necessarily opened or closed together. This is of prime importance as under no circumstances should one of

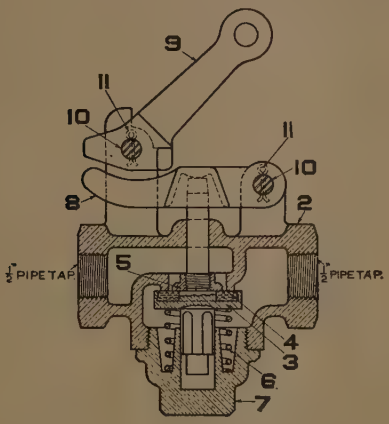


Fig. 28. Conductor's Valve.

these pipes be open and the other not. Whenever it is necessary to cut out the brake on a car, this cock should be closed by turning the handle until it is parallel with the pipes leading through it, thus cutting off all air supply to the triple valve and auxiliary reservoir.

In the control pipe branch pipe to the triple valve is placed a *combined air strainer and check valve*, Fig. 32,

which allows the air from the control pipe to flow into the triple valve to assist in charging the auxiliary reservoir, but not in the opposite direction. This check valve

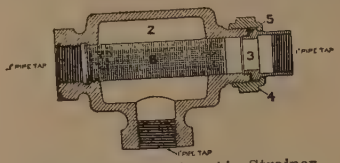


Fig. 29. Brake Pipe Air Strainer.

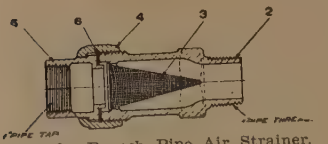


Fig. 30. Branch Pipe Air Strainer.

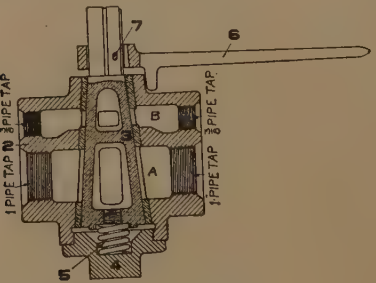


Fig. 31. Double Cut Out Cock.

therefore prevents the escape of the air stored in the auxiliary reservoir, and consequent loss of braking power, in case of loss of control pipe pressure due to

burst hose, parting of train, or other cause. An arrow is cast on the body of this valve to indicate the manner in which it should be installed.

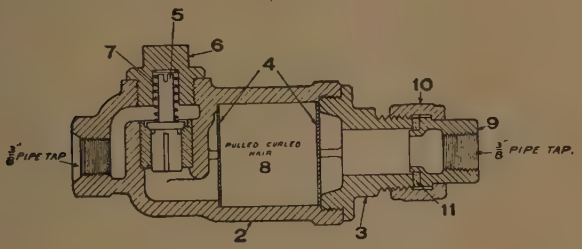


Fig. 32. Combined Air Strainer and Check Valve.

The *triple valve*, Fig. 3, may be attached directly to the cylinder head, to a bracket underneath the car, or to a stand inside the car.

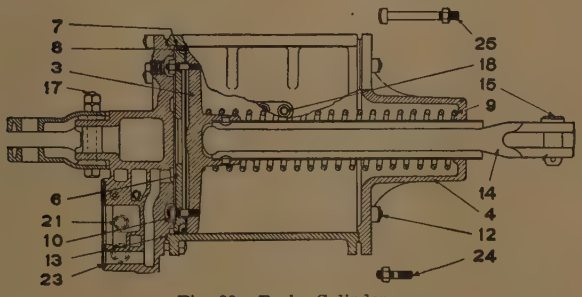


Fig. 33. Brake Cylinder.

The *auxiliary reservoir* should be located as near the triple valve as possible, and where its drain cock can be easily reached from the side of the car. Its volume is

such that when charged to 70 lbs. it will equalize with the brake cylinder at 50 lbs. pressure.

The brake cylinder (Fig. 33) should be located as near the triple valve as possible, and in such a manner as to be convenient for inspection. The piston 3 has a hollow rod in which is a solid push rod, 14, attached to the levers of the foundation brake gear. This allows the brakes to be applied by hand (when necessary) without moving the piston, but a pneumatic application forces out both hollow piston rod and push rod. The movement of the brake gear must therefore be free from binding, or undue friction, and adequate means provided for both hand and air brake systems, to insure that the push rod shall return fully home when a release is made. The release spring, 9, forces the piston to release position when the air pressure is exhausted from the opposite side of the piston.

The packing leather, 7, is pressed against the cylinder wall by the packing expander, 8, and prevents the escape of air past the piston.

Inspection and Maintenance. In cleaning the cylinder and piston, special attention should be given to removing lint, freeing the leakage groove of any deposit, and thorough cleansing of the expander ring, packing leather, and piston. In oiling or greasing the cylinder, special attention should be given to the thorough lubrication of the top of the cylinder and the inside of the packing leather where the expander ring rests. A light grease has been found to give the best results in the cylinder. If too much oil be used it will work back into the triple valve and ruin the rubber-seated check valve and gasket. It should be particularly observed that the follower nuts are tight. The travel of the piston should

be adjusted to 4 inches (standing) as nearly as practicable. This is important for the reason that if the piston travel is too short, a high braking power will be obtained, when only a low braking power is desired, the equalization of the auxiliary reservoir and brake cylinder pressures will occur sooner, and the time in which the motorman can perform the operation is greatly reduced. On the other hand, if the piston travel is too long, a proper braking power is not obtained for a given reduction, and the final "equalization" pressure is lowered. If some brake cylinders in a train have long piston travel and others short, a very uneven braking power will be developed for any given brake pipe reduction; which will retard some cars more than others, and result in shocks and unnecessary strains on draw bars. This is one of the principal causes of wheel sliding.

The correct operation of the brakes can only be secured by maintaining a uniform piston travel on all cars. The increase in the slack of brake rigging, due to the wearing away of brake shoes, must be constantly watched and taken up by means provided in the brake rigging, thereby maintaining the piston travel as nearly uniform as possible. By far the best means for accomplishing this is to install, in all cases where possible, the Automatic Slack Adjuster. Where this is not done, proper inspection and adjustment must be made at sufficiently frequent intervals to prevent any material increase in piston travel. As this inspection and adjustment has to be made while the car or train is standing, it must be remembered that running travel in traction service is generally from ½″ to 1″ longer than standing travel, so that if a 5″ running travel is desired, the standing travel should be adjusted to about 4″. If the Auto-

matic Slack Adjuster is used, its pipe should be connected with the brake cylinder at the hole located 5⅜" from the pressure head.

Piston travel should never be altered to obtain sufficient shoe clearance. This should be obtained by using a brake cylinder of proper size for the brake force to be developed, and through proper proportioning of the foundation brake gear. When inserting new shoes to replace those worn out, the brake slack should be let out first, and the piston travel adjusted properly after the new shoes are in place.

All the *piping* should be so installed that there are no pockets in which moisture can collect and freeze in cold weather. Air strainers should be placed as closely as possible to the valves which they are intended to protect. All *cut-out cocks* should be placed where they can be easily reached, but protected from being closed accidentally. Handles should be in such a position that they would jar open instead of shut. Particular attention should be paid to the location of the flexible hose connections and dummy-coupling chains, to avoid kinking or chafing of the hose.

OPERATION OF THE EQUIPMENT.

Charging. To charge the system, place the brake valve handle in *running position*, at the extreme left and leave it there.

Service. To make a service application of the brakes, place the brake valve handle in the *intermediate service position*, if the train is composed of only one or two cars, but in *service position* if more than two cars are being operated. When a sufficient reduction in brake-pipe pres-

sure has been made to apply the brakes as required by the speed. condition of rail, grade, and kind of stop desired, move the handle back to *lap position*, where it should remain until it is desired either to release the brakes or to apply them with greater force. In the latter case, move the handle again to the service position previously used, further reducing the brake-pipe pressure until the desired result has been obtained, then return it to lap position.

A good motorman quickly acquires a knowledge of the amount of brake-pipe reduction necessary in any case. The heavier the reduction, the harder the brakes are set. Moreover, the retarding effect of any given reduction is relatively greater at low, than at high speeds. To make a quick, smooth stop, therefore, from high speeds, make a brake pipe reduction of 18 to 20 lbs., and graduate the release of the brakes (as described later) as the speed of the car or train is reduced, so that at the end of the stop little or no pressure remains in the brake cylinder. In equipments where the brake cylinder exhaust is piped to the brake valve, never move the brake valve handle to lap position to release the brakes.

RELEASING.

In releasing the brakes after an application, three things must be borne in mind:

1st. If the brake valve handle is placed in *Release and Running Position,* and left there, all brakes in the train will fully release.

2nd. If the brake valve handle is placed in *Release and Running Position* for a moment, and then moved to *Holding Position,* the brakes on all cars except the oper-

ator's will release fully, but the brake on the operator's car will not release (the brake cylinder exhaust being piped to the brake valve).

3rd. If the brake valve handle is placed in *Release and Running Position* for a moment, and then moved to *Lap Position,* the brakes on all cars will graduate or partially release.

A movement of the brake valve handle from *Release and Running Position* to *Holding Position* does one thing only, viz.: closes the brake cylinder exhaust port in the brake valve and prevents further escape of air from the brake cylinder to the atmosphere. This is the "Straight-Air Release" feature and plainly applies to the operator's car only.

In releasing it must be remembered that for a given pressure in the brake cylinders, the brakes will stop the train quicker at low than at high speeds. Consequently, having a certain brake cylinder pressure at the commencement of a stop, which should be as high as the conditions already mentioned will allow, the pressure should be reduced as the speed decreases in order to keep the retarding effect of the brakes uniform. Otherwise the train will come to a stop with a jerk. The "Graduated Release" feature enables the operator to take care of *this very thing,* and he soon becomes able to do this as the speed of the train diminishes so that the train comes to a standstill without any shock and at the point desired.

Brake pipe reductions beyond the point of full application give no additional cylinder pressure, but do materially lengthen the time required in which to release the brakes, on account of the time required to recharge the depleted brake pipe. From this it is clear, also, that

if a graduated release is attempted after such an over-reduction, the handle may be moved to *Release and Running Position* and returned to *Lap Position* without raising the brake pipe pressure above that of the auxiliary reservoir. Therefore the triple valve piston does not go to release position, and there can be no graduation of the release. Over-reductions, therefore, waste air, are of no benefit, and interfere with the proper release of the brakes. As a brake pipe reduction of from 18 to 20 lbs. gives a full application of the brakes under normal conditions, this should be regarded as the limit.

EMERGENCY POSITION.

The emergency position of the brake valve should be used only when it is necessary to stop the car within the shortest possible distance to save life, or prevent accident. In this position the port connecting the brake pipe to the atmosphere is much larger than in service position. The reduction in brake pipe pressure therefore takes place suddenly, and the triple valve parts move to emergency position, with the result that the maximum cylinder pressure possible with the equipment is obtained quickly, and maintained until released by the motorman.

PRACTICAL TRAIN TESTS.

In preparing the car or train for service, and before making the following tests, follow carefully the rules given under the heading Charging:

Test No. 1. When the system is charged, and the governor stops the compressor, apply the brakes in serv-

ice from the head car, with a brake pipe reduction of 10 lbs., indicated by the black hand of the duplex gauge, and return the handle to lap position. The brake inspector should then proceed at once along the side of the train and note whether the push rod of each cylinder has moved out such a distance as to indicate that the brakes are properly applied on all cars. If any brake releases after the service application, examine all the cut-out cocks under the brake valves which are supposed to be cut out. Such a release is probably due to one of those cocks not being properly closed, a leak in the auxiliary reservoir, or its connections, or open auxiliary reservoir drain cock. It may also be caused by a brake valve not being properly "lapped," by a leaky rotary valve, by a leaky brake cylinder packing leather, by the piston travel being so short that the piston did not travel beyond the leakage groove, or a closed brake pipe or branch pipe cut-out cock may have prevented the brake from applying. If any improper operation is observed during this test it should be corrected before proceeding with the next test (See Test No. 5 in this connection).

Test No. 2. Following Test No. 1, after having noted that all the brakes in the train apply after a service reduction, release the brakes by placing the brake valve handle in *Release and Running Position.* Leaving the handle in *Release and Running Position,* the brake inspector should again return along the side of the train to the rear car, examining all push rods to see that they have moved back to "full release," and that all brake shoes hang free from the wheels. Should any of the brakes fail to release or "stick," when the brake valve handle is placed in *Release and Running Position,* the

trouble may be due to the feed valve not opening, to the cock in the brake cylinder exhaust pipe being closed, a brake valve not being properly lapped, or to a feed valve back of the operator's car being set higher than that on the operator's car, and a control pipe cut-out cock between the cars being closed. After having made sure that all of the cocks in the train are properly open, or closed, as the case may be, make a heavy brake pipe reduction, after which place the handle in release and running position. If a first or second trial of this does not succeed in releasing the brakes, the brake rigging, triple valve, piping, etc., should be examined in turn, and the trouble located.

Test No. 3. With installations having the brake cylinder exhaust piped to the brake valve, a test should be made to insure that the brakes on the operating car will not release with the brake valve handle in holding position. Make about a 15 lb. service reduction and place the brake valve handle in holding position. All brakes in the train should now release, except those on the operating car. If its brake does release, there is probably a leak in the brake cylinder exhaust pipe, or the brake cylinder exhaust pipe cut-out cock at the other end of the car may be open.

Test No. 4. While it is ordinarily safe to assume that the brakes will apply on an emergency application, provided they apply satisfactorily in the service Test No. 1, yet the brakes should occasionally be tested by making an emergency application with the brake valve, and also with the conductor's valve, in order to make sure that no obscure causes exist which would interfere with this most important function of the system.

Test No. 5. If it is observed or suspected that an

emergency application of the brake is obtained on any car in the train, when only a service application is intended, the following test should be made to locate the improperly acting triple valve:

After permitting the system to charge up to full pressure, make a service reduction, not exceeding 7 lbs., and place the brake valve handle in Release and Running Position. If any brake in the train takes a noticeably longer time to release, and exhausts with more noise than the others, it is the offender.

HINTS TO MOTORMEN.

CUTTING OUT BRAKES.

It is very important not to cut out the brake on any car unless it is absolutely impossible to operate it safely. Small leaks are not sufficient cause for thus reducing the braking power on the train as a whole. After cutting out the brake on any car (by closing the double cut-out cock in the branch pipes) release its brake by opening the auxiliary reservoir bleed cock, and leaving it open.

SWITCHING CARS.

In setting cars out of a train, first close the brake pipe, and control pipe cut-out cocks, separate the hose couplings *by hand,* and attach the dummy couplings. Never allow the hose couplings to be jerked apart by the separation of the cars, since this inevitably results in defective hose, and consequently in very unsatisfactory brake operation. In setting the hand brake on the car set out of the train, be sure that the air brake has been released. The foundation brake rigging on some cars is so constructed that the hand and power brakes pull in opposite directions. It therefore follows that if the hand brake on such cars is set while the air brake is applied, both brakes will be released, when the brake cylinder pressure leaks off.

UNEXPECTED BRAKE APPLICATIONS.

Such applications may be due to the use of the conductor's valve, the train breaking in two, a bursted hose, or other rupture in the piping. In such event the motorman should at once place his brake valve handle in lap position. This prevents the escape of control pipe, and main reservoir pressure, and enables prompt release of the brakes when the signal is given to go ahead.

CONDUCTOR'S VALVE.

Should the conductor find it necessary to set the brakes, the cord or handle of the conductor's valve should be pulled down as far as possible and held until the train stops. This valve must be closed, of course, before signalling the motorman to go ahead; otherwise brake pipe pressure will continue to escape and the brakes cannot be released.

RAIL SANDING.

Whenever it is necessary to sand the rails this should be done, if practicable, before the brakes are applied, for the reason that if the brakes are set and the wheels begin to slide, the application of sand will—in all probability—prevent their revolving again, and flat spots are almost sure to result. In such an event the best practice is to release the brakes slightly at the moment of applying the sand, after which a much higher brake cylinder pressure can be used without causing the wheels to slide. If sand is used, the rails should be well and continuously sanded until the stop is made, or the brakes released.

REVERSING MOTORS.

Ordinarily the car motors should never be reversed while the brakes are applied, on account of the danger of locking the wheels, and thereby increasing the length of the stop. As a last resort, however, the motors may be reversed to prevent a collision or save life. In such a crisis use plenty of sand, especially on a bad rail. The motors may also be reversed if the brakes are disabled.

BRAKE PIPE RUPTURE.

Should the brake pipe hose burst, or other rupture occur in the brake pipe, rendering the brakes in the rear thereof inoperative, the hand brakes on such disabled cars should be tested, and someone assigned to use them if necessary to control the train. Close the brake pipe cut-out cock on the end of the car just ahead of the point of rupture, release the brakes, and proceed with the train as usual; operating the available brakes at the head end of the train until the damage can be repaired. Where it is possible, protection against further rupture of hose, or break-in-two of the train back of the first break may be easily secured by simply placing one of the brake valve handles on that section of the train in release position. This fully charges the section of the train back of the closed angle cocks, thus insuring an automatic emergency application of the brakes on that section, should its brake pipe or hose become ruptured from any cause.

CONTROL PIPE HOSE BURSTING.

Close the control pipe cut-out cocks immediately ahead of and behind the defective hose and proceed with the train as before.

BRANCH PIPE RUPTURE.

Should a branch pipe break between the triple valve and the double cut-out cock, close the double cut-out cock, release the brakes on that car by opening the auxiliary reservoir bleed cock, and proceed as usual.

If the break occurs between the double cut-out cock and the brake pipe, close both the control pipe and brake pipe cut-out cocks at the front end of the disabled car, release all brakes in the rear by opening the auxiliary reservoir bleed cocks, and proceed with the train, operating the head brakes as before.

GENERAL HINTS.

To gain time, adapt the brake pipe reduction, or application of brakes, to speed. For example, for high speed make a full application and graduate off when a short distance from the stop. To handle the train smoothly, make application heavy and soon enough, so that if held on, the train would stop a car length or so short of the mark. Then as the stop or mark is approached, graduate the pressure out of the brake cylinder so that little remains when stop is made. If on a level, complete the release; if on a grade, hold until the signal to start is given, then release. As the pressure has been graduated down so that little remains in the cylinder, it will be seen that the start can be made promptly.

TRIPLE VALVE.

A separate pipe bracket or brake cylinder head is included in the equipment to which all pipe connections to the triple valve are permanently made. It is therefore known as a "pipeless" triple valve. No pipe connections need to be disturbed in order to remove the valve, the loosening of three nuts being all that is required. Care should be taken in locating the valve to have it free from obstructions which would render inspection or removal difficult, and that it is as far as possible above the general level of the piping so that no pockets are formed in the latter. If this point does not receive proper attention, trouble may be experienced in cold weather from the freezing of water in the pipes or valve itself. Under ordinary service conditions the triple valve should be thoroughly cleaned and lubricated once in three months. The proper interval is best determined for each particular case by a careful inspection and trial. Where conditions are severe and the triple valve exposed to extremes of weather, dirt and so on, more frequent inspections will, no doubt, be found necessary. Where the valve is protected and not subjected to hard usage, the interval may be lengthened. The use of heavy grease, or other lubricant which will "gum" and cause the valve to work stiff, or clog the ports, should be avoided. Too light a lubricant or one that does not possess sufficient "body," is not satisfactory, as it will not thoroughly lubricate the parts or last as long as necessary. Special lubricants made for this purpose will be found the most satisfactory.

Never remove the movable parts of the triple valve while it is on the car. If the valve is not working

properly, or needs cleaning and oiling, take it down and replace it by a valve in good condition, and have all cleaning and oiling done at a bench, by a competent man and where liability of damage to the internal parts of the valve is least. Any attempt to take the triple valve apart while still on the car is almost sure to result in a large percentage of valves being injured by careless handling, or dirt getting inside the pipes or valve. Before installing the triple valve, all the piping should be thoroughly hammered and blown out, in order to loosen and remove all pipe scale or foreign matter. This is especially important in new installations. After the installation is complete, all the joints should be thoroughly tested under pressure with soap-suds and made air tight.

QUESTIONS AND ANSWERS ON THE AUTOMATIC BRAKE SYSTEM.

1. Q. What was the first form of air brake called?

A. The straight air brake.

2. Q. How does the air apply the brake?

A. By being admitted to the brake cylinder, and forcing the piston out, which, by means of connecting rods and levers, pulls the brake shoes against the wheels.

3. Q. How is the brake released?

A. By allowing air in the brake cylinder to escape to the atmosphere. The release springs on the trucks then force the brake rigging back, and the shoes leave the wheels.

4. Q. Name the principal parts of a straight air brake.

A. Electric switches, fuse block, governor, compressor, main reservoir, operating valves and brake cylinder.

5. Q. What controls the amount of air pressure in the main reservoir?

A. The governor.

6. Q. Where is the governor connected electrically?

A. In the compressor circuit, between the fuse and the compressor.

7. Q. What does the governor do?

A. It allows current to flow to the compressor until a predetermined pressure is reached in the main reservoir, when it automatically breaks the circuit and thus cuts off the current from the compressor.

8. Q. How much difference should there be between cutting in and cutting out pressures?

A. Fifteen pounds.

9. Q. Name the pipe connections to the operating valve, used with the straight air brake?

A. Main reservoir, brake cylinder, and exhaust.

10. Q. In applying the straight air brake, where does the air go?

A. From the main reservoir through the operating valve to the brake cylinder.

11. Q. In releasing this brake, where does the air go to?

A. From the brake cylinder through the operating valve to the exhaust.

12. Q. What parts are essential on a car equipped with automatic brakes in addition to those named for a straight air brake?

A. A triple valve, feed valve and auxiliary reservoir.

13. Q. Why is such a brake called an automatic brake?

A. Because it will apply the brakes automatically by any reduction of the brake pipe pressure, no matter how it is caused.

14. Q. What part of the brake equipment causes this action?

A. The triple valve.

15. Q. Where does the air come from that goes to the brake cylinder in the automatic application?

A. The auxiliary reservoir.

16. Q. Is the Westinghouse brake equipment known as schedule AMM a straight air or automatic brake?

A. Automatic.

17. Q. How many pipes are connected to the brake valve with this equipment?

A. Four.

18. Q. What are they?

A. Brake pipe, control pipe, brake cylinder exhaust pipe, and brake valve exhaust pipe.

19. Q. From the brake valve, where does the brake pipe lead to?

A. The brake pipe is continuous throughout the length of the car, connecting to the triple valve under the car and has hose connections at the terminals for the purpose of connecting it to other cars.

20. Q. From the brake valve, where does the control pipe lead to?

A. The same as the brake pipe.

21. Q. Follow the air from the compressor to the auxiliary reservoir.

A. From the compressor to the main reservoir, then through the feed valve to the control pipe which leads to the brake valves and triple valve. From the brake valve through the brake pipe to the triple valve and through two ports in the triple valve to the auxiliary reservoir. There is also a port in the triple valve through which air passes direct from the control pipe to the auxiliary reservoir.

22. Q. What three particular advantages does the control pipe provide?

A. Quick recharge, graduated release and high pressure in emergency.

23. Q. What are the principal working parts of the type M triple valve?

A. The triple piston, slide valve, graduating valve and by-pass valve.

24. Q. What are the different operating positions of the triple valve?

A. Release and charging position, quick service position, full service position, service lap position, graduated release lap position, and emergency position.

25. Q. What are the positions of the brake valve?

A. Release, holding, lap, intermittent service, and emergency.

26. Q. Trace the port openings, with the triple valve in release and charging position.

A. Referring to Figs. 5 and 6, air releases from the brake cylinder through *x*, *n*, *w*, *m* and *p*, to the brake cylinder exhaust pipe which leads to the brake valve. At the same time the auxiliary is being recharged from the brake pipe through *a*, *e*, *c*, *f*, *g*, *h* and *i*, and through *x*, *y* and *k*.

27. Q. In what position is the brake valve handle with the triple in release and charging position?

A. It may be in holding or release position.

28. Q. Will the air in the brake cylinder exhaust to the atmosphere with the triple valve in release and charging position?

A. Not unless the brake valve handle is in running position.

29. Q. Why does not release take place with the brake valve on holding position?

A. Because the connection between the brake cylinder exhaust pipe, and brake valve exhaust pipe is closed.

30. Q. What is the purpose of the holding position of the brake valve?

A. To provide straight air release on the car on which the brake valve is being operated.

31. Q. What pressures are in the control pipe, brake

pipe and auxiliary reservoir when the triple valve is in release and charging position?

A. If it has been in this position long enough for the air to release from the brake cylinder, they are all equally charged to 70 pounds, or whatever the feed valve is set for.

32. Q. How is the triple valve changed from release and charging position to quick service position?

A. By reducing the pressure in chamber slowly, which is the brake pipe pressure side of the triple piston. The auxiliary reservoir pressure, which is on the opposite side of the piston, moves the piston slide valve and graduating valve in the direction of the weaker pressure to the quick service position.

33. Q. What then takes place?

A. Air passes from the auxiliary reservoir through ports *z* and *r* to the brake cylinder, until the auxiliary reservoir pressure has dropped slightly below the brake pipe pressure, which, being now the greater pressure, causes the triple piston to move carrying the graduating valve with it until it strikes the slide valve and the graduating valve covers port *z*, cutting off the flow of air from the auxiliary reservoir to the brake cylinder, as shown in Fig. 9.

34. Q. What is done to cause the triple to move to quick service position?

A. The brake valve is moved to the proper service position to cause a slow reduction of the brake pipe pressure which is shown by the black hand of the gauge.

35. Q. What is done to cause the triple valve to move to full service position?

A. The brake valve is moved to the proper service

position to cause a more rapid reduction of the brake pipe pressure.

36. Q. What is the difference between the quick service and full service position of the brake valve?

A. On account of the brake pipe reduction being more rapid, the auxiliary reservoir pressure forces the piston, slide valve and graduating valve farther, so that a full opening through port *z* in the slide valve and port *r* to the brake cylinder has been made, which allows the air to flow from the auxiliary reservoir to the brake cylinder more rapidly.

37. Q. What is the purpose of the quick service feature?

A. It allows a further reduction of the brake pipe pressure after the brake valve has been returned from making a slow reduction (intermittent service position on a single car) to lap position, by a passage from the brake pipe through check valve 9, port *y*, *o*, *v*, *q* and *r*, to the brake cylinder.

38. Q. What position of the triple valve allows this action?

A. Quick service position only.

39. Q. What causes the triple valve to move from release position to emergency position?

A. Any sudden reduction of the brake pipe pressure due to the conductor's valve being opened, or a hose or brake pipe being ruptured, or the valve handle being placed on the emergency position.

40. Q. Trace the port openings of the triple valve in emergency position.

A. Air flows from the auxiliary reservoir through ports *l* and *r* to the brake cylinder. Air also flows from the auxiliary reservoir through ports *s* and *t* to the face

of the by-pass valve piston 13, forcing the by-pass valve open, allowing the air to flow from the control pipe through *x*, *r*, *r*, and *r*, to the brake cylinder.

41. Q. Is the pressure obtained in the brake cylinder by an emergency application any greater than by a service application?

A. Yes.

42. Q. How much?

A. About 30 per cent.

43. Q. Why?

A. On account of the additional pressure being pressure received from the control pipe.

44. Q. What is meant by saying the brake is fully applied?

A. That full brake cylinder pressure has been obtained in either service or emergency application.

45. Q. How do the auxiliary reservoir and brake cylinder pressures then stand, compared with each other?

A. Equal.

46. Q. How much must the brake cylinder pressure be reduced to produce this?

A. About twenty pounds.

47. Q. After the brake is fully applied, will a further reduction of the brake pipe pressure be of any benefit?

A. No.

48. Q. What will be the result of reducing the brake pipe pressure more than necessary to fully apply the brakes?

A. It will waste air, and cause the release to be delayed in proportion to the amount of the over reduction.

49. Q. In order to release the brakes what must be done?

A. The brake pipe must be recharged, as soon as brake pipe pressure exceeds auxiliary reservoir pressure, the triple valve will be forced to release position.

50. Q. How is graduated release at the triple valve obtained?

A. By allowing the brake pipe to only partially recharge, then quickly return the brake valve from release position to lap.

51. Q. Trace the connections in the triple valve when graduated release takes place.

A. The brake pipe pressure is increased slightly above the auxiliary pressure, forcing the triple valve to release position, allowing the air to discharge from the brake cylinder through ports, *r*, *n*, *w*, *m* and *p*. At the same time the auxiliary reservoir is being recharged from the control pipe through *x* and *k*, and from the brake pipe through *a*, *e*, *c*, *f*, *g*, *h* and *i*, and through check valve 9, *y*, *j* and *n*. The auxiliary reservoir is thus recharged while the air exhausts from the brake cylinder. Then when the auxiliary reservoir pressure is increased slightly above the brake pipe pressure the piston and graduating valve are forced to graduated release lap position, shown in Fig. 10, and all connections are blanked, the exhaust from the brake cylinder and the auxiliary reservoir recharging ports being closed.

52. Q. How may further graduations be obtained?

A. By additional increases of the brake pipe pressure according to the amount of air it is desired to release.

53. Q. When is it desirable to graduate the release of the brakes as just described?

A. When operating two or more motor cars in a train,

54. Q. Can a motor and trailer car both be released in this manner?

A. Yes, if there is a control hose line between the cars in addition to the brake pipe hose connection.

55. Q. How is graduated release obtained with a motor car alone or with a motor car and trailer without the control line connection between the cars?

A. By moving the brake valve handle to release position and returning it to holding position to retain any desired amount in the brake cylinder.

56. Q. What pressure is always carried in the control pipe?

A. Seventy pounds or whatever pressure the feed valve is set for.

57. Q. What will cause the brakes to set without the brake valve handle being moved from release position?

A. The conductor's valve being opened.

58. Q. What should the motorman do when the brakes are thus applied by the conductor?

A. Place the brake valve handle on lap position and hold it there until car stops.

59. Q. What else will cause the brakes to set without movement of the brake valve handle?

A. The rupture of the main reservoir piping, the control pipe, or brake pipe, or any of the hose connections. They will also set if compressor stops, on account of any trouble in the electric circuit.

60. Q. In what position may the triple valve be with the brake valve on lap position?

A. If the brake valve has been moved to lap from release position, the triple valves will be in lap positions.

61. Q. Should the car or train if running have the power applied with the brake valve on lap position?

A. No.

62. Q. How should the brakes be tested before starting with a single car?

A. Place a handle on the valve to be operated, and move it to release position, and open the cut-out cocks immediately under it. Close all the cut-out cocks under the brake valve at the other end of the car. See that the cut-out cocks are closed at the hose terminals, and the double cut-out cock near the triple valve is open. See that the drain cocks in the main and auxiliary reservoirs are closed. Then start the compressor and wait until full air pressure is pumped up. When this is done apply the brakes fully by making a reduction of twenty pounds in the brake pipe pressure.

63. Q. What then should be done?

A. Inspect the brakes to see that they apply properly.

64. Q. What should be looked for?

A. To see that the brake shoes are firmly against the wheels and the piston travel is not over 4½″ and not less than 4″. The brakes should then be released.

65. Q. What should be done after releasing the brakes?

A. See that the piston returns in the cylinder, and the shoes leave the wheels.

66. Q. When two or more cars are coupled together in a train what preparation should be made for testing brakes?

A. All hose couplings between the cars should be coupled, and the cut-out cocks near the hose terminals all opened except those at the front and rear ends of the train. All drain cocks should be closed. All the brake valves except the one being operated should have the handles removed, leaving these valves in lap position.

The cut-out cocks in the brake pipe under all valves except the one being operated should be closed. The cut-out cocks in the brake cylinder exhaust pipe should be open under all valves, except the one at the opposite end of the car which is being operated. See that the double cut-out cock near the triple valve on each end is open, then allow the pressure to pump up full, and test as with a single car.

67. Q. What should be looked for in case the brakes cannot be applied by the brake valve?

A. First see that the cut-out cocks under the brake valves are open. Next see that the double cut-out cock near the triple valve is open.

68. Q. What is the best method of making a stop with a brake of this type?

A. After the controller has been moved to "off" position, make a heavy service reduction in the brake pipe pressure, then as the car or train slows down, graduate the brakes off so that by the time the stop is made there will be a very light pressure in the brake cylinders.

69. Q. When inspecting the cars at the car barn what should be done to the pump governor?

A. See that it is adjusted to cut in at 85 pounds, and cut out at 100 pounds.

70. Q. What will happen if the cutting in pressure is too low?

A. Blowing the whistle may set the brakes. The brakes may fail to release after a light application has been made.

71. Q. What attention should be given to the feed valve?

A. It should be adjusted for 70 pounds pressure,

using a test gauge if there are motor cars working together in a train, so that all the valves will have the same adjustment.

72. Q. What will happen if they are not adjusted alike?

A. The car having the one with the lowest setting will have to supply more air than the others, especially when there is a control pipe connection between the cars.

73. Q. What will happen if the feed valve feeds up or overcharges the system?

A. The brakes will set when blowing the whistle and fail to release promptly, or it may be impossible to release when a brake application has been made.

74. Q. What should be done when this occurs?

A. If the brakes will not release after making a heavy reduction, or returning the brake valve handle to release, drain the auxiliary reservoir, and proceed to where the defective feed valve may be replaced.

75. Q. What should be looked for in the feed valve, if on making a light brake application, the brakes do not release?

A. The feed valve is sluggish due to lack of lubrication, and the brake pipe pressure does not increase properly when the brake valve is returned to running position.

76. Q. How often should a feed valve, and triple valve be oiled?

A. Once a month.

77. Q. What lubricant should be used?

A. Marvin's Anti-Friction Triple Valve Oil is the best.

78. Q. What care should be used in oiling these parts?

A. In removing the piston and slide valve they should be handled with extreme care so as to prevent the surfaces being scratched or dented, causing them to leak. The valves, seats, piston and cylinder should be carefully wiped with a clean cotton cloth, and a small amount of oil put on these parts.

79. Q. How often should a brake valve be oiled?

A. Once every month.

80. Q. What may be wrong if the brakes set when the brake valve handle is moved from release to lap position?

A. There may be a leak in the brake pipe.

81. Q. What is the result when the brake shoes are adjusted so close that the piston will not travel 4″ with the brakes fully set?

A. The brake applications will be too severe, and a light brake application may not make enough reduction to cause the feed valve to open and, consequently the brakes stick.

82. Q. What is the result when there is too much shoe clearance making a long piston travel?

A. The brakes will be too slow in applying and releasing, and the maximum cylinder pressure will be lowered. There will be, also, an excessive waste of air, causing the compressor considerable undue work.

83. Q. How should the brake cylinder be tested for a leaky leather?

A. Make a full application and return the brake valve handle to lap position, and measure the piston travel. Note the brake pipe pressure to see that it does not build up and release the brakes. If at the end of 15 minutes the piston has not moved more than ½″ the packing leather may be considered tight.

84. Q. What test would be made to determine whether there is a leak in the brake cylinder exhaust pipe?

A. After making test in answer to question No. 83, if this shows no leak, make a full application and return the brake valve to holding position and allow it to stand there 15 minutes and note whether the piston moves more than ½", and if it does not the brake cylinder packing leather, and exhaust pipe are both tight.

85. Q. Which of the above tests is most important?

A. The latter, because the brake valve handle should be left on holding position to hold a car.

86. Q. How often should this test be made at the car barn?

A. Once a month.

87. Q. How often should brake cylinder packing leathers be greased?

A. Once every six months.

88. Q. How should brake cylinder packing leathers be lubricated?

A. Remove the piston from the cylinder and put a thin coating of grease on the cylinder wall near the pressure head.

89. Q. Why should not oil be used?

A. Because it runs to the lower part of the cylinder, making the leather soft at that point. If oil is used it is usually put in by removing a plug in the pressure head, and an excessive amount put in which carries dirt and grit into the triple valve.

90. Q. If the brake pipe pressure increases after a reduction has been made with the brake valve handle on lap position, what should be looked for?

A. The brake valve should be examined to see if the

rotary valve seats properly and is not dirty, as this trouble may be caused by a leak under the rotary valve.

91. Q. What attention should be given to the motor-driven air compressor?

A. It should be lubricated regularly with a good quality of oil (Artic Ammonia oil or some equally as good) and when oiling the compressor part, extreme care should be used to make sure that this oil fitting is filled, and remains full after oil has been poured in. The commutator should be kept clean. If there is any knocking, the lost motion in the connecting rods should be taken up.

92. Q. What attention should be given to the suction and discharge valves in the compressor?

A. They should be cleaned once a month.

93. Q. What is the reason ordinary oil is not satisfactory to use in air compressors?

A. When air is compressed, excessive heat is produced, which destroys the lubricating quality of oil not made expressly for this purpose.

94. Q. If oil is running out of the holes near the bottom of the motor, what should be done?

A. This is due to the overflow drain on the chamber between the pinion and armature bearing, and the bottom of the gear case being closed. This should be cleaned out.

95. Q. Of what does the equipment of a trailer car consist?

A. An auxiliary reservoir, brake cylinder, triple valve, double cut-out, check valve and strainer, conductor's valve, brake and control pipes.

96. Q. In what respect does a trailer car differ from a motor car?

A. It has no brake valves, alarm whistle, air compressor, governor, or main reservoir.

97. Q. Where should the air compressor be located on a motor car?

A. Near the side of the car.

98. Q. Why are two main reservoirs used?

A. For the purpose of storing an abundant supply of air for promptly releasing and recharging the system.

99. Q. Where should the main reservoir be located?

A. As low and as near the side of the car as possible, in order to keep the stored air cool.

100. Q. What is the function of the air strainer?

A. To prevent dirt or other foreign matter from entering the pipe.

101. Q. At what range is the electric pump governor usually set?

A. Fifteen pounds; that is, cutting-in pressure, 85 pounds, and cutting-out pressure, 100 pounds.

102. Q. How should the wiring be installed?

A. In as thorough a manner as possible, care being taken to avoid all possibility of grounds developing.

103. Q. Where should the compressor switches be located?

A. One at each end of the car, within easy reach of the motorman.

104. Q. Where should the fuse box be located?

A. Between the last compressor switch and the governor.

105. Q. At what pressure is the safety valve set?

A. One hundred and ten pounds.

106. Q. At what pressure is the feed valve usually set?

A. It is set to maintain a pressure of 70 pounds.

107. Q. Where should the duplex air gauge be installed?

A. In the direct line of vision of the motorman while running over the road.

108. Q. What type of valve is the brake valve?

A. It is of the rotary type.

109. Q. Name the different positions of the brake valve handle, and the function of each.

A. Release and running, in which air from the control pipe flows directly to the brake pipe. Holding position, in which air from the control still flows into the brake pipe, but the exhaust from brake cylinder is shut. Lap position, in which all ports in the valve are blanked, except the brake cylinder exhaust port. Intermediate service, in which connection is made from brake pipe to atmosphere through a smaller opening. Service position, in which connection is made from brake pipe to atmosphere through a larger opening. Emergency, in which a much larger opening is made from brake pipe to atmosphere.

110. Q. To where does the brake pipe extend after leaving the brake valve?

A. Throughout the train, similar to the control pipe.

111. Q. Where may the conductor's valve be placed?

A. At any convenient point in the car.

112. Q. What occurs when this valve is opened?

A. The air in brake pipe flows directly through it to the atmosphere, thus setting the brake.

113. Q. What is the function of the double cut-out cock in the branch and control pipes?

A. To open or close both these pipes at the same time.

114. Q. Where should the triple valve be attached?

A. Either to the cylinder head, to a bracket underneath the car, or to a stand inside the car.

115. Q. Where should the auxiliary reservoir be located?

A. As near the triple valve as possible.

116. Q. What is its volume relative to that of the brake cylinder?

A. Its volume is such that when charged to 70 pounds it will equalize with the brake cylinder at 50 pounds pressure.

117. Q. What is required of the movement of the brake gear?

A. It should be free from binding or undue friction.

118. Q. Describe the arrangement by which the brakes may be set by hand when necessary?

A. The piston in the brake cylinder has a hollow rod in which is a solid push rod.

119. Q. How is the brake cylinder piston packed?

A. With leather packing.

120. Q. What is the best lubricant for the inside of brake cylinder?

A. A light grease gives the best results.

121. Q. What should the travel of the piston be?

A. It should be adjusted to 4 inches.

122. Q. What is the result if the piston travel is too short?

A. A high braking power will be obtained when only a low braking power is desired.

123. Q. What results when the piston travel is too long?

A. A proper braking power is not obtained for a given reduction.

124. Q. What is the result when some brake cylinders in a train have long piston travel and others short?

A. A very uneven braking power will be developed

for a given reduction, which will retard some cars more than others.

125. Q. How then may a correct operation of the train brakes be secured?

A. By maintaining a uniform piston travel on all cars.

126. Q. What is the function of the automatic slack adjuster?

A. To take up the slack in the brake rigging and thereby maintain the piston travel as nearly uniform as possible.

127. Q. How should the piping be installed?

A. In such a manner that there will be no pockets in which moisture can collect.

128. Q. Where should the air strainers be located?

A. As close as possible to the valves they are intended to protect.

129. Q. In what position should the brake valve handle be to charge the system?

A. In running position at the extreme left.

130. Q. Where should the brake valve handle be placed to make a service application?

A. In intermediate service position if for one or two cars, but in service position if more than two cars are being operated.

131. Q. What three things must be remembered in releasing the brakes?

A. 1st. If the brake valve handle is placed in release and running position and left there, all brakes in the train will be released. 2d. If the brake valve is left in above position only for a moment, and then moved to holding position, the brakes on all cars except the operator's will release. 3d. If the brake valve is placed

in release and running position for a moment and then moved to lap, the brakes on all cars will graduate or partially release.

132. Q. If the brake valve handle be moved from release and running position to holding position, what takes place?

A. The brake cylinder exhaust port is closed.

133. Q. How may the train be brought to a stop without a jerk?

A. By means of the graduated release, viz., allowing the pressure to be reduced, as the speed decreases.

134. Q. What are some of the disadvantages of over-reduction of pressure in making an application?

A. A waste of air and interference with graduated release.

135. Q. What should be the ordinary reduction in making an application of the brakes?

A. From 18 to 20 pounds.

136. Q. When should the emergency position of the brake valve be used?

A. Only when it is necessary to stop the car within the shortest possible distance.

137. Q. In making test No. 1 what reduction of pressure is made?

A. Ten pounds, as indicated by the black hand of gauge. All of the brakes should then be set.

138. Q. How is test No. 2 made?

A. Following test No. 1, place the brake valve handle in release and running position. This should fully release all brakes.

139. Q. What is the object of test No. 3?

A. To insure that the brakes on the operator's car will not release with the brake valve handle in holding position.

140. Q. What reduction is required in test No. 3?

A. About 15 pounds, then place handle in holding position.

141. Q. What should now take place?

A. All brakes in the train should now release, except those on the operating car.

142. Q. How is test No. 4 made?

A. By placing the brake valve handle in emergency position, and also using the conductor's valve.

143. Q. What is the object of test No. 5?

A. To ascertain whether an emergency application takes place on any car, when only a service application was intended.

144. Q. What should be done in cutting out a brake on a car?

A. Close the double cut-out cock, then open the auxiliary reservoir bleed cock, and leave it open.

145. Q. What precautions should be observed in switching, or setting cars out of train?

A. Always separate the hose couplings by hand, and be sure that the air brake is released before setting the brakes by hand.

146. Q. If an unexpected application of the brakes should occur, caused by the train breaking in two, or a conductor's valve being used, what should be done?

A. The brake valve handle should be at once placed in lap position.

147. Q. How should the conductor's valve be used?

A. The cord or handle of the valve should be pulled down as far as possible, and held until the train stops.

148. Q. Give the proper method of sanding the rails?

A. If practicable the sand should be applied before the brakes are set.

149. Q. Why?

A. Because if the brakes are first set, and the wheels begin to slide, the application of sand will then prevent their revolving again, thus causing flat spots.

150. Q. How may this generally be prevented?

A. Slightly release the brakes at the moment of applying the sand.

151. Q. Should the motors be reversed while the brakes are applied?

A. No, as there is danger of locking the wheels by doing this.

152. Q. As a last resort what may be done?

A. Reverse the motors, and use plenty of sand.

153. Q. In case of bursted hose, or rupture in the train pipe occur on any car, what should be done?

A. Close the brake pipe cut-out cock on the end of the car ahead of the point of rupture, and assign some one to use the hand brakes on the disabled cars.

154. Q. In case of control pipe hose bursting what must be done?

A. Close the control pipe cut-out cocks immediately ahead of and behind the defective hose, and proceed with train?

155. Q. Should a branch pipe break between triple valve and double cut-out cock what must be done?

A. Close double cut-out cock and release the brakes on that car?

156. Q. If the break in branch pipe occurs between the double cut-out cock and brake pipe what should be done?

A. Close both the control pipe and brake pipe cut-out cocks at the front end of the disabled car, release all

brakes in the rear by opening auxiliary reservoir bleed cocks, and proceed.

157. Q. What precautions should be observed in locating the triple valve?

A. To have it free from obstructions, so that it may be easily inspected or removed.

158. Q. How often should this valve be cleaned and oiled?

A. Ordinarily, once in three months.

159. Q. Is it a good plan to take the triple valve apart while it is on the car?

A. It is not. This work should be done by a competent man at the shop bench.

160. Q. Before installing the triple valve what should be done with the piping?

A. It should be hammered and blown out in order to clean it.

161. Q. After installation is complete what test should be made?

A. All of the joints should be thoroughly tested under pressure with soapsuds, and made airtight.

THE STRAIGHT AIR BRAKE.

In order that the student may clearly understand the difference between the straight air brake system, and the automatic air system (which has already been described) the following simple comparison of the two systems is presented:

In the automatic air system there is an auxiliary reservoir in close proximity to the brake cylinder on each car. Between the brake cylinder and the auxiliary reservoir is placed a triple valve; all the triple valves on a train are connected to each other and to the motorman's valve on the motor car through the train line. The triple valve is operated by a reduction of pressure in the train line, which is accomplished by moving the handle of the motorman's valve so as to open a port communication from the train-line to atmosphere. When the pressure in the train line is reduced 10 to 18 pounds, the triple valve automatically operates, establishing an opening between the auxiliary reservoir and the brake cylinder. The triple valves on all cars in the train operate almost simultaneously, and the compressed air has only to flow a short distance from the auxiliary reservoir to its particular brake cylinder.

In the straight air system the air receiver consists of a single large reservoir charged to a high pressure. To operate the brakes the motorman turns the handle of the operating valve to such a position as will provide an unobstructed opening for compressed air to flow from the reservoir to the brake cylinder; thus as positive and

reliable setting of the brakes as is possible is secured, combining maximum simplicity with absolute certainty. The velocity of air under high pressure is so great that the time elapsing before the pressure is equalized between the reservoir and brake cylinder on the last car of a train of two or three cars, is so brief as to be practically instantaneous, giving as almost simultaneous application of brakes on all of the cars in the train as is possible with the automatic system.

An advantage possessed by the straight air system consists in the ability of the operator to increase or decrease the amount of pressure in the brake cylinder at will and with a fine degree of accuracy; whereas to decrease the pressure in the automatic system it is necessary to release the brakes entirely and re-apply them to the desired degree, unless the system is equipped with the graduated-release feature. This feature of the straight air system can be taken advantage of quite frequently when the car is coasting down long variable grades, as well as when making a stop that must be accurately accomplished at a given point.

THE NATIONAL STRAIGHT AIR TRACTION BRAKE.

Fig. 34 shows a view of the general arrangement of the National Straight Air Brake Equipment on a double truck electric car, and Fig. 35 is a diagram of the system as applied to a motor car, with trailer attached. The location of the various parts of the equipment depends upon two main factors, first, the existing electrical apparatus under the car, or to be installed there;

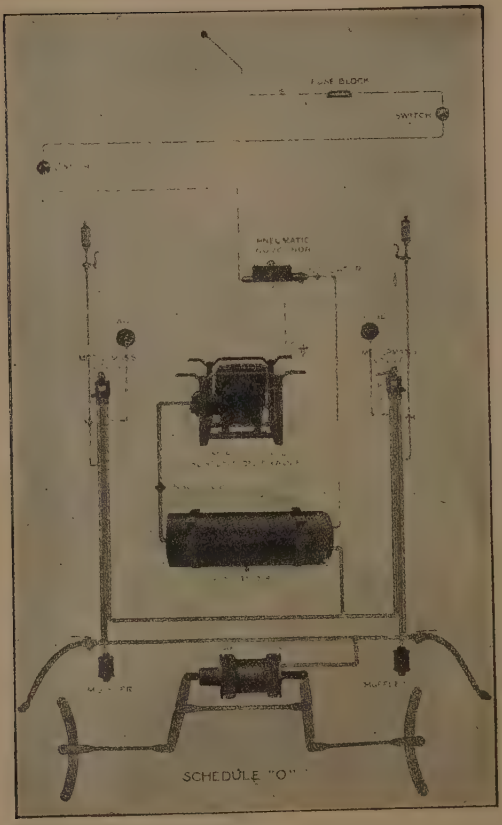


Fig. 34. National Straight Air Brake Equipment for Double End Electric Motor Car.

second, those parts requiring care and inspection should be located in positions most easily accessible.

Following is a list of the several necessary devices that go to complete this system:

1st—An Air Compressor driven by an independent electric motor, and supplying the compressed air.

2nd—An Automatic Governor which stops and starts the air compressor, thereby maintaining the pressure and regulating the supply of compressed air.

3rd—A Main Reservoir in which the compressed air is stored.

4th—A Brake Cylinder with piston rod connected to the brake levers in such a manner that when compressed air is admitted into the brake cylinder by means of the motorman's operating valve, the piston is forced outward by the compressed air and the brake shoes applied against the wheels.

5th—A Motorman's Brake Valve placed at each controlling point of the car, by means of which the compressed air is admitted from the main reservoir to the brake cylinder, and from the brake cylinder to atmosphere.

6th—A specially constructed Piping System connecting the main reservoir with the motorman's brake valve, and the pipe leading from this valve and extending throughout the entire length of the train; the latter is termed the Train Pipe, and is fitted with flexible hose and couplings between the individual cars, with a stop cock at each end of every car and an auxiliary pipe leading to the brake cylinder arranged under each car.

7th—A System of Wiring, including switches and fuse boxes, which connects the main trolley circuit to the compressor and governor.

8th—The Hose Couplings with which each end of every car is equipped, and by means of which the train pipes on the cars are connected to form a continuous train pipe line.

9th—An Air Gauge of the single hand type to indicate the pressure in the main reservoir only. An air

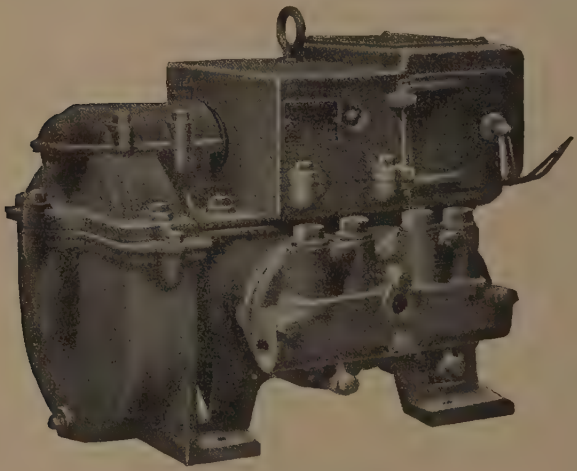


Fig. 36. A-1 Compressor.

gauge provided with two hands is sometimes employed, one of which indicates the pressure in the main reservoir, and the other the pressure in the train pipe, the former hand being colored red, and the latter black.

10th—A Safety Valve to prevent any possibility of over-charging the main reservoir, and the piping system.

11th—Also frequently required is a chime whistle operated by air pressure, used as a warning signal instead of a bell or gong.

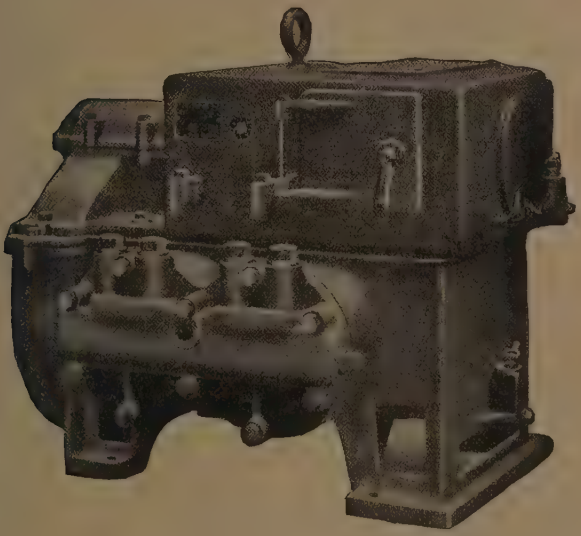


Fig. 37. National BB-2 Type Compressor.

INSTALLING THE MOTOR COMPRESSOR.

The most desirable location for the motor compressor is under the car body. On account of the thoroughly dust-proof and water-proof construction of the A-1, A-4, BB-2, CC-3 and DD-4 type compressor, the equipment does not include an enclosing box for the motor compressor. It is claimed by the National Brake & Elec-

tric Company that the elimination of the enclosing box is an advantage, as it allows a free circulation of air around the compressor, thus tending to keep it cool and increasing its efficiency. There is furnished with each

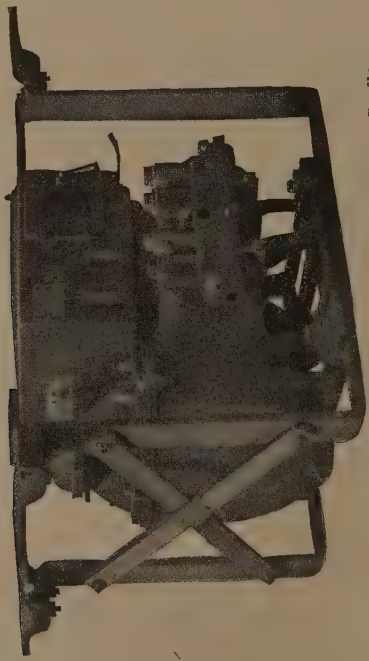


Fig. 38. A-4 Compressor Mounted in Suspension Cradle.

compressor a light, rigid suspension cradle constructed of wrought iron bars. This cradle, shown in Fig. 38, combines strength with compactness and easy accessibility to all parts of the compressor requiring attention.

The base of the compressor is bolted directly to the tie bars, which are insulated from the hangers by fibre and hard wood insulation. The above named parts comprise the cradle proper suspended from the crossbars, which in turn are bolted directly to the car body. The compressor being very strongly supported by the wooden blocks and crossbars, its vibrations are completely absorbed, and hence no strains are caused on the car body. The compressor may be quickly removed from the suspension cradle by raising it about one-half inch and sliding out four bolts.

Fig. 39. Motor Complete.

The selection of the most desirable position for the motor compressor under the car is largely governed by the amount of apparatus already there. The chosen place should be such as will ensure freedom from heated air from the resistance grids or car motors, and such that all oil holes in the compressor pump base will be readily accessible from the street. The air supply can be piped from any convenient point in the vestibule or roof of the car. The suction pipe has at its extremity,

a suction strainer filled with pulled, curled hair with a fine mesh screen over the opening. The method of installing is as follows:

The compressor should always be installed with its shaft crosswise of the car and with the gear inside, or as near the center of the car as possible.

The base of the compressor should be securely fastened to the suspension cradle, taking care to tighten cap

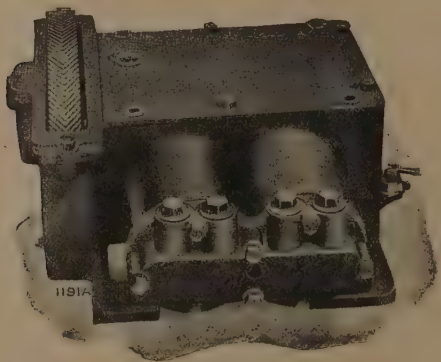


Fig. 40. Pump Complete.

screws and nuts solidly. Then attach the crossbars firmly to the car framing at uniform and proper distances apart. If the under framing is not suitably arranged to conveniently receive the crossbars, secure one of the crossbars to a piece of the car framing, and insert a suitable timber for the other. Eight $\frac{5}{8}$-inch bolts should be employed for each crossbar. Lag screws are not permissible for this purpose. It is permissible to bend up

the ends of the crossbar and bolt them to the side of the sill. When the compressor must be removed from the cage it will be found that the construction of the cage is such that the compressor will readily come out through two sides of the cage without removing any part of it. The vent openings in the side of the pump base are for

Fig. 41. A-2 Type Compressor from Gear End.

the purpose of carrying away any vapors that may be generated within it. These openings should never be closed, or made smaller. The connections to the main reservoir should all be made at the opposite end from that at which the discharge from the pump enters, in order to insure passage of air through the reservoir, and

the deposit of water that may be precipitated in the cooling of the compressed air; likewise any oil or dirt that may have been carried along with it.

Looking at the motor compressor from the gear end (see Fig. 41), the pump shaft should rotate clock-wise and the motor shaft in the opposite direction. The direction of rotation of the armature may be changed by reversing the brush holder connection.

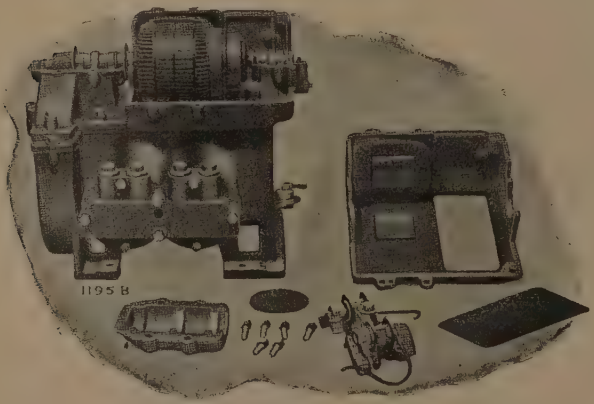


Fig. 42. Compressor Dismantled to Remove the Armature.

A card showing the arrangement and connections of the straight air brake equipment is attached to each compressor sent out and should be carefully studied. In connecting up the wiring of the compressor the positive wire of the circuit should be connected to the lead extending through the motor frame nearest the commutator door. Connect the other lead to the negative side

of the circuit. The set screws on the brass terminals must be tightly set, and the terminals completely wrapped with insulating tape.

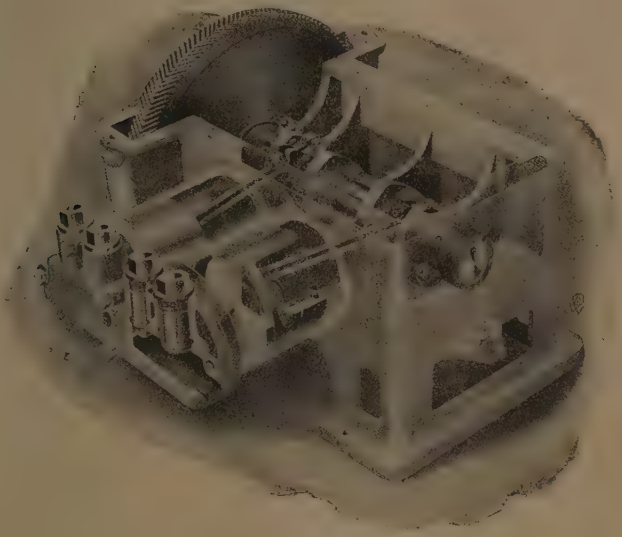


Fig. 43. Phantom View of Compressor Base.

INSPECTION AND MAINTENANCE.

While the instructions for installing the compressor as herein given may serve as a good guide, they should not be considered as ironclad rules. On account of the arrangement of the existing equipment differing so widely on different cars, and other conditions varying so much, the judgment of the master mechanic must neces-

sarily be exercised in a large degree in determining the method of installation. In other words, what might be good practice for one road might be altogether unsuited to a different road.

The air compressor and its driving motor require but nominal attention. The following are the most important points in their maintenance: 1st—The oil is introduced into the pump chamber through oil holes or plugs which are arranged as shown in Fig. 49.

Fig. 44. Piston, Rings and Connecting Rod.

A good quality of engine oil should be used, such as will suffer no change from the high temperatures sometimes reached in the crank chamber after long operation of the pump. The oil used should also have a low freezing point. The bad results obtained from the use of crude, unpurified oils in causing abrasion of the cylinders, and losing body under high temperatures will greatly over-balance the low first cost obtained by this policy. Inspection should be made at least every other day, and the oil supply regularly replenished once a

week; oftener if necessary. About every two and a half months at the least, the drain plug 6 (Fig. 49) should be opened and the oil drained off for filtering. 2d—The armature bearings should be regularly inspected and oiled when needed. The armature bearing on the commutator end is oiled through filling plug 46 and does not require any further attention except that the oil

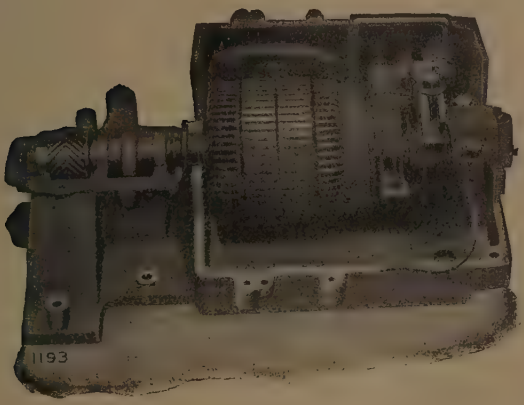


Fig. 45. Lower Half of Motor.

should be replenished when inspection shows this to be necessary. The bearing at the gear end should be oiled through filling plug provided for that purpose. This bearing requires no further replenishing after the pump has once been started, as the oil is constantly replenished by the motion of the gear.

The armature is removed by taking out the cap screws 55 which fasten the field frame to the motor base; then disconnect the brush holder leads and the field coil leads, and after removing the brush holder, unscrew the cap screws, which secure the top half of the motor bearing housing, take out cotter pins 53, after which pinion 74 may be pulled off. It is necessary that the armature should be free to move in the opposite direction, as the gear teeth prevent the pinion from moving outwardly.

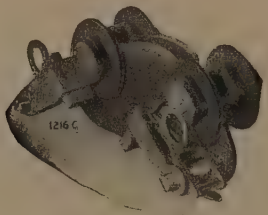


Fig. 46. Brush Gear Complete.

The armature may now be lifted from its position, much care being taken to prevent it from striking against pole pieces, and injuring the cross sections at the end of the core.

In replacing the armature, slide it carefully into the fields until the threaded end projects from the bearing with the key-way up. The pinion should then be slid into position and a small lever used to force it into alignment with the shaft.

Replace the head with the commutator bearing, care being taken to keep grit and dirt out of the bearing and from the oil rings; and see that the oil rings are in their proper position on the shaft. The electrical connections

should be made exactly as before, and the brushes also replaced as original to preserve the same brush pressure on the commutator.

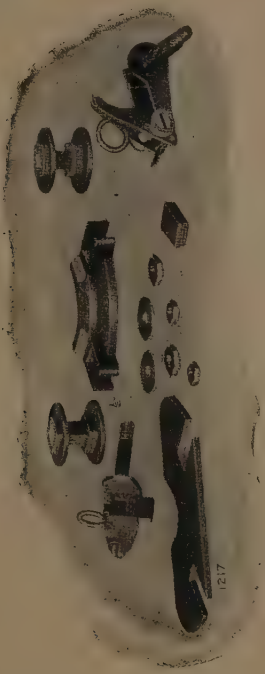


Fig. 47. Brush Gear Disassembled.

While the pinion is still uncovered, turn the armature by hand to determine whether the gears run freely; then screw the bearing shell back into place and run the compressor with the motor long enough to pump full

pressure in the reservoir. The arrangement of the suspension cradle is such that the disassembling, and reassembling may be easily done while the compressor is in position under the car, and either operation can be done by one man who has had a short experience in this work, and is provided with a standard wrench for this purpose.

3. If the field coils must be removed the compressor should be taken from the car and since this operation is easily accomplished with the National type of suspension, when a suitable kind of jacking apparatus is provided in the pit, it is very advisable that roads using air brake equipments, keep several extra compressors on hand, so that a damaged one may be easily replaced and the repairs made in the shop during day hours which can be done to a better advantage than at night.

4. The commutator should be kept clean, but not necessarily highly polished; a rich glossy bronze is most desirable. The brushes should always have a good contact, and also be free in their holders. The brush tension can be increased, or decreased, by means of the carbon adjustment. When it becomes necessary to turn down the commutator, due to wear by the brushes or other causes, particular care should be taken to bevel off the corners slightly on the end of the bars. If the bars are left with a sharp edge, the mica is more likely to crumble away and cause a short circuit from bar to bar; the mica will then become carbonized, and the commutator in time ruined. In removing the commutator, the oil guard which is shrunk on the shaft should first be taken off either by heating with a blow torch or by turning off on a lathe; the commutator can then be pulled off easily with screws in the usual way. A new oil guard must be shrunk on and finished like the old one.

5. If for any reason the brush gear must be disassembled, especial care should be taken to have the brush lead as originally adjusted. This adjustment is readily effected by screw 120. Ordinarily there will be no occasion for changing the brush adjustment, as the

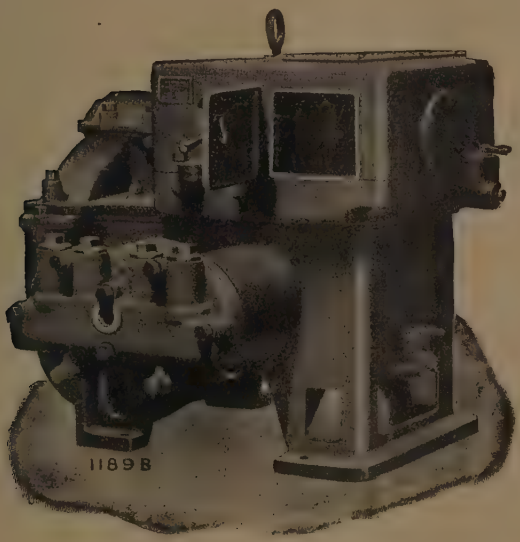


Fig. 48. Type A-4 National Compressor.

entire motor can be taken apart without doing so, since the brush holder yoke is attached to bearing cap 42 only.

6. When removing the pinion from the armature shaft, always use a pinion puller. Never use a sledge hammer for this purpose.

7. When removing the gear from the crank shaft, use a wooden mallet on the rough part of the gear; in such cases great care should be taken not to injure the teeth, as they will only have to be repaired again before the compressor can be put in service. Since the tendency of the pinion is to wear the gear teeth at the two points corresponding to the dead centers of the crank shaft, there are two key-ways 90° apart for turning the gear one-quarter.

8. If the suction and discharge valves wear irregularly, they as well as their chambers should be thoroughly cleaned in gasoline at least once every six months. The valves should be removed and their cavities thoroughly cleaned with vaseline. *Never put any oil on the valves.* The suction strainer should be cleaned once every week when oiling to avoid the accumulation of dirt therein with consequent reduction of compressor efficiency.

9. In assembling the motor compressor, much care should be taken to have the gear and pinion mesh properly, since a defect in the meshing of the gear will result in a pounding or grinding noise when the compressor is operating. The best results are obtained by having a play of about one-sixty-fourth of an inch between the teeth.

If a pounding develops in the compressor, remove the pump base cover, and adjust the crank bearings of the connecting rods by taking out some of the washers provided for this purpose. The connecting rod caps are adjusted by means of these shims which, when removed one by one, draw the connecting rod caps into better bearing surface on the crank shaft. Be sure to tighten the lock nuts and replace the cotter pins.

To remove the piston packing rings or the wrist pin, the connecting rod must be detached from the crank shaft. After removing the cylinder head, the piston can be taken out.

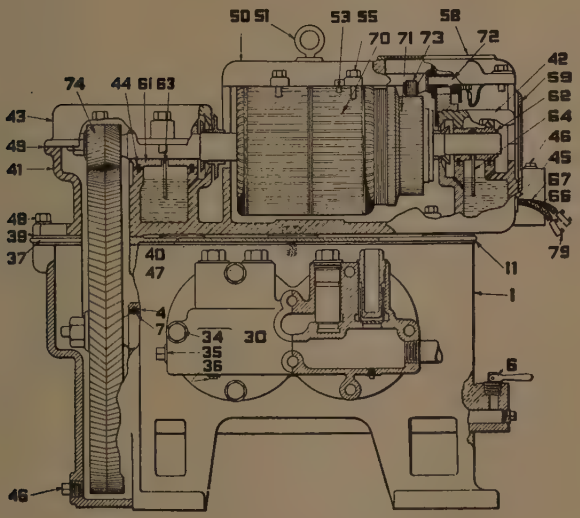


Fig. 49. Front Sectional Diagram of Compressor.

Some care must be taken in replacing the packing rings, as their diameters and faces are nicely ground. In replacing the piston rings they are first assembled in the groove on the piston with their springs; a flexible wire is then wound once around the piston ring. By pulling both ends of the wire the ring will be drawn to the diam-

eter of the bore of the cylinder, which then makes it easier to push the piston back to its original position.

In removing the wrist pin, take out the set screw, and by gently tapping the small end of the wrist pin with a block and mallet the pin is easily removed.

10. Insulation couplings should be kept tight and in perfect order; regular inspection of these parts is therefore necessary.

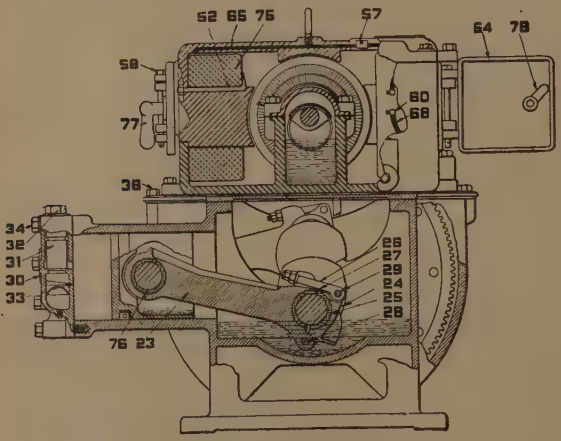


Fig. 50. Sectional Diagram of Compressor.

If the compressor is constantly blowing its fuse and the motor is working properly, it may be assumed that the fault is in the pump. Inspection will likely show that the discharge valves are sticking or that the piston is operating with considerable friction in its cylinder, due to insufficient lubrication, or that a hot bearing

exists. Under no circumstances should a heavier fuse be substituted for the size advised on a given compressor, as a burned out motor may result.

The sizes of fuses which are recommended for the different types of compressors, when operated on 550 volt currents, are as follows:

COMPRESSOR NUMBER	AMPERES OF FUSES AT 550 VOLTS.
A-1	6
A-2	6
A-4	6
BB-2	10
BB-4	10
CC-3	15
DD-4	20

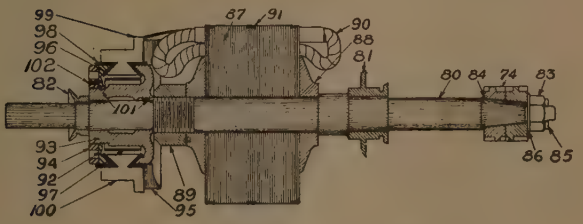


Fig. 51. Sectional Diagram of Compressor Armature.

DIRECT CURRENT, SERIES WOUND MOTOR COMPRESSOR—TYPE A-4.

Fig. 48 shows a view of this type of compressor, and Figs. 49 to 53 inclusive present sectional elevations showing the various parts in their relation to each other. The numbers used in the following description apply to the different sections. The air passes into the cylinders

through the suction valve chambers 31 (see Fig. 50). The air intake pipe is fitted with strainer screens, filled with pulled, curled hair. The design of the mesh of these screens, and the arrangement of the absorbent is such that all dust, and foreign matter is stopped before it reaches the cylinder. After passing the suction valves, the air flows through ports into the cylinders. On the return stroke of the pistons the air is forced through the discharge ports, past the discharge valves, and from thence to the discharge pipe. The suction and discharge valves are made of hard, cold drawn tubular steel, and are easily accessible, and removable. By unscrewing the valve caps 32 on top of the cylinder head, all valves are accessible. The valves being seated by gravity, springs are unnecessary. The complete trunk pistons 18 (see Fig. 52) are fitted with carefully ground piston packing rings 19. When dismantling the pump, each ring should be used, with the piston on which it was originally fitted. The piston wrist pins 21, on which the tail end of the connecting rods work, are of hardened, carefully ground steel, and are held in place by the set-screw 22. Working on them is the bronze bushing 76 (Fig. 50) in the connecting rod 23. The lining of the crank under the connecting rod is a special quality of babbitt metal, and is hinged at its lower end, and fastened by an eyebolt 26, at the upper end. The thin steel shims 27 are removable, so that as the bearing wears the strap may be tightened on the others, and locked with a jam nut. It is very essential that the shaft should rotate with the compression part of the stroke on the upper half of the revolution or in a clock-wise direction, when viewed from the gear end. The crank shaft 12 (Fig. 52) is of special grade steel, liberally propor-

tioned with large size outside caps 2 and 3, of lumen. Bushings 4 and 5 run through the center. The lubrication of all these parts is effected by a bath of oil with which the crank case is filled through the screw plug 6 (Fig. 49), which is fitted with a handle. The gear 17 (Fig. 52) on the overhanging end of the crank shaft is made of a special high carbon steel, and is constructed of two halves, which are solidly riveted together, thus constituting the very efficient herringbone type of gear. It is driven onto the shaft over a square key, and rigidly fastened by a large nut.

THE MOTOR.

The motor is a four-pole enclosed series wound type, provided with a cast steel housing 50 (see Fig. 49), made in one piece, and fitted with hinged doors over the commutator end, which give easy and quick access to the brushes and commutator. The hinged door 54 (Fig. 50) covers the opening tightly, and thoroughly excludes dust or rain. The armature bearings rest on supports 41 at each end of the frame, and are provided with oil wells, so arranged that flooding the interior of the motor with oil is impossible. The armature bearings 61 and 62 are amply dimensioned cast iron shells, lined with high grade lumen metal, and fastened with dowel pins 44. Two oil rings are used on each bearing, which gives positive assurance that the bearing will be lubricated as long as there is any oil in the well. An overflow pipe 47, at the pinion end of the bearing, extends to the bottom of the crank case, and absolutely prevents any of the gear oil which might escape from the pinion bearing from flooding the motor. The four field poles are a part of

the frame 50, two being arranged in a horizontal plane in order to reduce the height of the compressor. The field coils are clamped in position by clamp bolts 52 provided with a nut. The armature is built up of soft steel

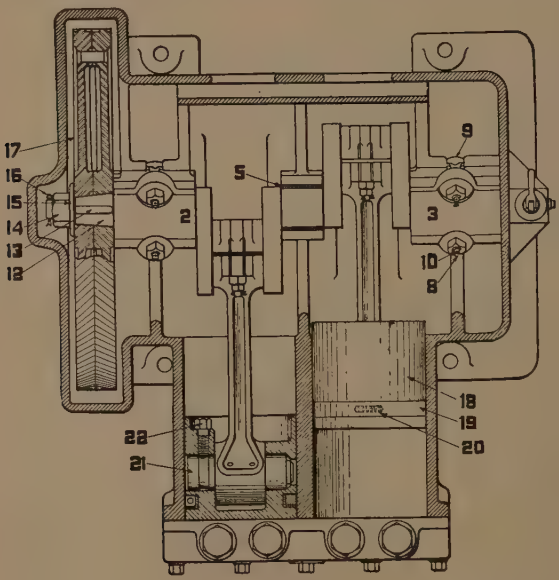


Fig. 52. Sectional Diagram of Compressor Base.

laminations 87 (see Fig. 51) with carefully punched slots in which are laid uniformly proportioned, machine wound coils. The commutator bars 100 are deep, and long and are amply insulated from each other by high grade mica segments 99. Much care is bestowed upon

the support of the leads from the coils to the commutator bars. This support consists of an insulating ring resting on the commutator sleeve 93. The end portions of the coils are also banded with piano wire 91, over insulation tape to safeguard them from damage due to centrifugal force. The two brush holders 72 (Fig. 53) are supported on the adjustable cast iron yoke 105. They are of cast brass, and are held in place by the hexagonal nuts 109 and 110, and threaded to the body of the holder. The brush holders are well insulated from the yoke by a shield 113, cap screw 120, and washers 114 and 115. The carbon brushes 73 fit in machined guides, and are maintained in contact with the commutator by coiled steel tension springs 111, which keep a uniform tension throughout the life of the brush. As all of these compressors are primarily intended for operating electric railway brakes, they must be operated intermittently, and even then a limit is imposed upon the length of time they can be safely run, due to temperature rise in the motor. The maximum continuous run which is advisable to operate them is given in the following table:

PRESSURE	OPERATION	REST
130 lbs.	10 minutes	20 minutes
100 lbs.	15 minutes	15 minutes
65 lbs.	15 minutes	15 minutes
20 lbs.	25 minutes	5 minutes

This table will serve as a good guide for the operation of ordinary railway compressors in average service, and shows the maximum continuous run which is recommended for compressors operating at various pressures, and the interval of rest required.

For use on single truck cars the National Brake & Electric Company has developed and manufactured a very compact and conveniently installed type of compressor termed the A-2 type (shown in Fig. 41), which has a capacity of 11 cubic feet of free air per minute, and which is constructed of the same high grade materials and with the same care in workmanship as those of larger output.

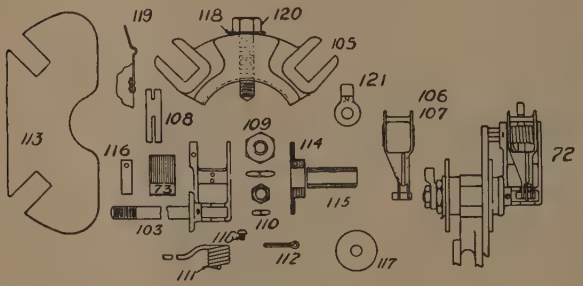


Fig. 53. Brush Holder and Parts.

The essential differences in design of the A-2 compressor and the A-4, and the various other types of larger capacity, are a modified form of air pump base, and such an arrangement of the gear case, as to greatly reduce the height of the compressor. The motor is of the open, instead of the enclosed type, which feature contributes toward making it of lower height than the compressors of larger capacity. These alterations in design over Standard types were made for the purpose of producing a compressor which could readily, and conveniently, be placed under a car seat with the gov-

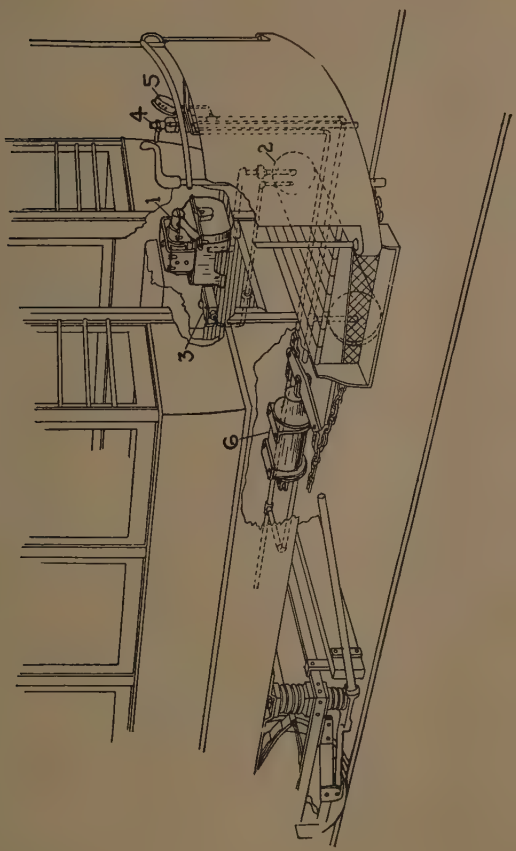


Fig. 54. Single Truck Car Equipment with A-2 Compressor.

ernor. The arrangement and sequence of the parts of an equipment in which the A-2 compressor is used, is clearly shown in Fig. 54. The motor compressor 1 is located under the car seat near the door, and almost directly over the reservoir 2. In this position the compressor is fully protected from dust, dirt and the weather and the motor therefore requires no enclosing case, which would be a detriment as it would prevent the free radiation of the heat which is generated by the motor, as well as interfere with the quick and easy inspection of the commutator, brushes and other parts. The governor 3, which is of the standard oil-pneumatic type, is located in close proximity to the compressor, and immediately over the reservoir, its position being quite advantageous as the temperature of the air near the compressor is always closely uniform.

The motorman's valve 4 and the gauge 5, which are the standard National Types as described in following pages, are arranged directly in the cab and take up very little space. The brake cylinder 6 is also of the standard type and placed in the usual position. The piping connections to the several parts of the equipment are shown in dotted outline, and are self-explanatory.

PNEUMATIC GOVERNOR.

The exacting conditions to which electric railway apparatus is subjected in these modern times necessitates the use of equipment that will render efficient service, but said equipment must be reliable and free from breakdowns. The reliable and efficient operation of motor driven air brake machinery depends in a large measure upon the reliability of the governing unit, which

automatically maintains, or should maintain, a constant supply of compressed air at the required pressure. Some of the requirements of a trustworthy governor are, first, that it may be relied upon; second. that it be prompt,

Fig. 55. Governor Complete.

and entirely automatic in its action; third, that its design and construction be such that it will operate for long periods without requiring attention or repairs. Fig. 55 shows a view of the oil pneumatic governor with

which the National Brake & Electric Company's motor compressor is equipped. Fig. 56 shows the governor

Fig. 56. Governor with Cover Removed.

with the cover removed, and Figs. 57 and 58 are sectional views showing in detail the working parts of the device.

CONSTRUCTION OF TYPE "N" OIL-PNEUMATIC GOVERNOR.

Referring to Figs. 57 and 58, 1 is the complete base of containing case into which are cast the keyways for

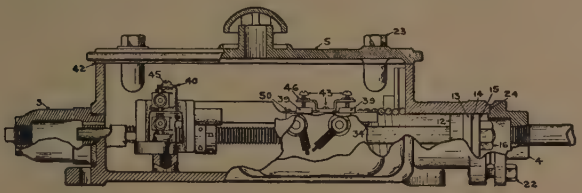


Fig. 57. Section of Governor. Type N.

fastening the forward end of the extension spring 21 and the contact arm stops. The containing case is fitted with a paper gasket 42, and the cover 5 and is screwed to

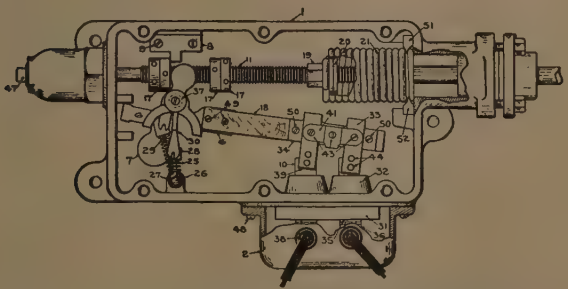


Fig. 58. Governor with Cover Removed. Sectional Diagram of Type "N" Governor.

lugs by means of screws 23. The piston 12 is equipped with double cups or gaskets 24, made of a special composition material which is not affected by oil. The cylin-

der head 4 is screwed in position by screws 22. The piston 12 works in the air chamber guided by 3 on the opposite end of the piston rod which is securely screwed to base 1. The piston 12 with the packing rings 13 is held in position by a screw 16. The packing rings 13 are of a special design which allow no escape of air around the sides of the piston but at the same time permit the piston to move freely in the cylinder. 14 and 15 are piston followers. The piston rod carries the operating spring 21 and a spring adjusting yoke or collar 19 at its forward end to which the controlling spring is secured. The adjusting yoke is provided with a washer 20, the tension of the spring being adjusted by turning the hexagonal nut 19. The cylinder end of the spring is held in the containing box by the two keyways referred to above. These keys are shaped in such a way that the spring is held very rigidly; this makes a neat, substantial and strong method of supporting the spring.

The cylinder is tapped directly to the reservoir so that the piston is always subjected to reservoir pressure, and no waste of air can occur. The spring used is of large diameter and made of special heavy wire carefully tempered, and will withstand any strains likely to occur without becoming weakened. The piston rod is threaded at its lower end to receive the adjusting nuts 17 for varying the range between minimum and maximum pressures. Double nuts are used so that by holding one, and screwing the other the pressure between the two securely locks them together. These adjusting nuts are made round instead of square and are adjusted by means of a spanner wrench which militates against the temptation of a motorman with a monkey wrench, to tamper with the adjustment which the master mechanic has made.

A trip hammer of the "kodak shutter" type and made of brass, is pivoted on a post 37 between the adjusting

Fig. 59. Type "N" Governor Disassembled.

nuts, its function being to trip the switch arm to open and close the electric circuit. The trip hammer mechan-

ism which actuates the switch arm is accelerated by the action of the spring 29 supported on a pin 25 and fastened at one end by means of the pin guide 30 secured at the trip hammer end by means of a movable metallic block, or eccentric device working between parallel jaws cast as an integral part of the trip hammer. The other end is secured to the wall of the containing case by means of toggle pin 26 which fits in lugs cast into the governor case. A smaller, shorter spring 28 of one-eighth the power of the trip hammer accelerating spring, and separated by distance piece 27 from the former, prevents vibration of the switch arm when the circuit is open. The method of supporting this spring is identical with that of the accelerating spring.

The switch arm 18 is made of a special insulating material which experience has proven to be the most effective, and durable insulating material for air brake service, especially high tension brake work. Being always under oil, no deterioration of the insulating material can occur. The motion of the switch arm in either direction is limited by two stops cast into the end of the governor case.

The moving switch blade contacts 39 are of heavy square shaped phosphor bronze, and are adjusted by means of screws 43 and adjusting plate 41 so that the area of "wiping contact" may be increased or decreased as may be required. The stationary electric contacts 10 are heavy, square shaped plugs, and are insulated from the governor containing case by means of the heavy insulating bushings 32. Short-circuiting between stationary contacts and case is therefore impossible. The arrangement of the supporting screws for the stationary contact is such that they can be easily turned over to

present a new contact for the switch blade if the occasion should ever arise, which will be rare. The two terminals for the electrical connections are placed on the side of the governor case, and are thoroughly insulated from each other and the containing case by means of a thick fibre block 31, which eliminates all danger of short circuiting. The two terminals can be either trolley or motor connection, respectively, without in any way affecting the operation of the governor, hence there is no possibility of making a wrong connection. The terminals are protected from interference, and danger of contact by means of the rectangular metal cover 2 screwed to the governor case. The leads from the motor circuit are run through insulated holes, made either in the top or the bottom of this cover.

INSTALLATION.

A good location for the governor is under a car seat, inside the car, and as directly over the reservoir as possible. Connect the governor as directly to the reservoir as possible, so that pulsations in the air pressure, on account of the operation of the compressor, or a drop of pressure in the pipe leading from the reservoir, may be avoided as much as possible. The connecting pipe should be as short as possible; should have a downward slope towards the reservoir, and be free from pockets where moisture might collect and freeze.

See that the terminals are in good condition, and that the electrical circuit is continuous before putting the cover in position.

The governor case should be filled to within one-fourth of an inch of the top. Use any good mineral oil having

a high flash test, and a low freezing point. Do not use kerosene or animal oil. Screw the cover down tight before putting the governor in service.

OPERATION.

The Type N Governor is equally well adapted for operation by direct, or alternating current, and its performance is not affected in any wise by variations of voltage. The operation of the governor is also entirely independent of gravity or outside forces. When the compressor is operating and the air pressure increases, the force of the piston at once begins to expand the operating spring. As the pressure is increased towards a maximum, the upper adjusting nut forces the projecting end of the trip hammer over its center causing it, with the assistance of the accelerating spring, to deliver a quick blow to the switch arm which immediately knocks it out of contact and opens the circuit. The arc which follows is instantly suppressed by the oil.

The pressure at which the governor cuts in is regulated by the extension spring, which is adjusted for the desired pressure by screwing the hexagonal spring nuts on the spindle. Screwing the nuts forward on the spindle increases the tension of the spring and requires a higher air pressure for actuating the governor. By moving the nuts towards the piston, the tension of the spring is decreased, and a lower pressure on the piston will cut in the switch arm.

As the pressure approaches a maximum the two nuts on the piston side of the toggle regulate the range of its movement. The two corresponding nuts on the opposite side of the toggle also limit its movement as the pressure

approaches a minimum. These two sets of double nuts are merely two points for varying the time limit, in which maximum, and minimum pressure will be attained. The desired adjustment is effected by moving the nuts until the gauge indicates the required limits. A spring shoe device on each switch blade, fitted with screws, enables the blades to be raised or lowered. Tightening the screws forces down the U shaped spring, thus drawing the switch blades against the stationary contacts and increasing the area of "wiping" contact.

Fig. 60. Type "A" Governor Complete.

When it is necessary to change the adjustment of the governor, much care should be taken to prevent any organic matter from getting in the containing case, as it might cause some of the oil to carbonize and interfere with the satisfactory operation of the governor.

Fig. 60 shows the type "A" pneumatic governor man-

ufactured by the National Brake & Electric Company. This is a strictly pneumatic appliance, and is very simple in design and construction, as will appear by an inspection of Fig. 61, which shows the governor with the cover open. It consists of two main parts and a cover, which, when separated, expose the entire mechanism to view, thus giving ready access to all parts. A source of

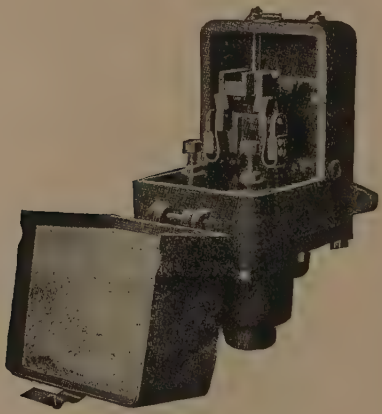


Fig. 61. Type "A" Governor with Cover Open.

serious trouble in motor-driven compressor governors has been the magnetic blow-out coil for suppressing the arcing, which causes the burning out of contacts, thus making the operation of the governor unreliable. In the type "A" pneumatic governor an air blow-out has been provided which extinguishes the arc, and also keeps the enclosing case free from dust and dirt. Only two ad-

justing screws are used, one for maximum and one for minimum pressures, and these screws are accessible when the governor is installed either under the car body or underneath a car seat. This type of governor is adapted for operation on either direct or alternating current, and variations in pressure or voltage will not affect its operation.

Referring to Fig. 62, giving side and end sectional elevations, there are three operating portions, viz., cut-out, cut-in and main or switch operating portion. These portions are enclosed in a cast iron containing case, which is divided into two parts so as to allow all valve mechanism to be readily removed when desired. These two parts are securely fastened together by cap screws, and are dowelled so that in reassembling perfect alignment between all moving parts is assured. A cover 3 made of sheet iron, and fastened to the containing case by means of a hinge and bolt, is provided, and gives quick access to the adjusting screws and contact shoes, as well as to the two terminals. As will be noted, the connecting wires for the motor are brought through the frame 1, protected by suitable insulating bushings 29 and connected to the terminals 16, which are mounted on an insulating block 30, securely fastened to the casing 1, thus insulating each terminal from the other as well as from the frame casing.

When the main piston 4, or piston carrying the circuit closer is in cut-in position, the circuit between the terminals is closed by a short circuiting device 27, mounted on the end of the contact carrier 25, which in turn is mounted on the piston rod 23. This short circuiting device is provided with removable contact shoes 19, and is also insulated from the piston rod by means

of the insulating block 28. By the admission of sufficient air pressure under the main piston, the short circuiting device is moved upward, and away from the contact shoes 18, of the terminals. At the same time a blast of air from the blow holes N, N, is allowed to pass across the faces of the contact shoes 18 and 19, thereby extinguishing the arc, and reducing the burning effect on the contacts to a minimum.

In order to keep the contact carrier and the contact shoes in perfect alignment at all times the outer ends of the contact carrier operate on two parallel guides 24. A spring tension device, which is an integral part of terminals 16, on which the contact shoes 18 are mounted, enables the tension of the shoes to be increased, or decreased by means of screws 17. The cut-out and cut-in portions are very simple and have few parts. The pilot, or high pressure valve 5, is similar in construction and operation to any ordinary pop safety valve. When the air pressure acting upon the under, or reservoir, side of the valve becomes high enough to overcome the tension of the spring 13, with which the valve is loaded, the valve moves upward sufficiently to allow the air that passes across the valve seat 21 to act upon the increased area which is then exposed, thus overcoming the pressure of the spring, and instantly moving the valve to its full upward position, and suddenly opening direct connection between the main piston chamber 1 and the reservoir. The cut-in portion consists of a metal diaphragm 6, a diaphragm keeper 9, which is threaded and securely fastened in position, a pin valve 8, a spring 12, and a guide 7. To relieve the diaphragm of all strain when exit valve 8 is open, a set screw with lock nut 26 is provided, which takes the pressure of spring 12 off the

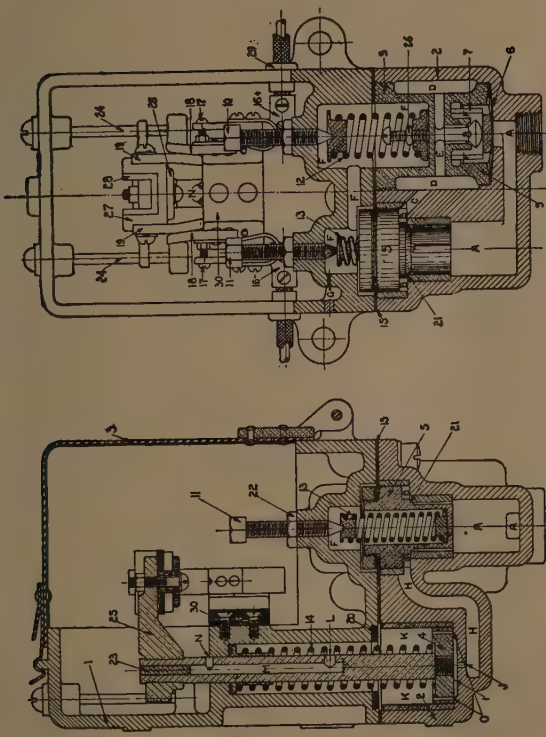


Fig. 62. Diagram of Type "A" Governor Showing Parts and Air Passages.

diaphragm. A gasket 15 of suitable material, is provided between the parts of the containing case so as to seal the air chambers from the atmosphere. Adjusting screws 10 and 11, with lock nuts 22 are used for the regulation of the high and low pressure portions.

Fig. 62 shows the governor in "no pressure" position, with all valves and the piston in the lower extreme of their travel. As is obvious, after the main switch has been closed, current will pass from main switch and fuse to the terminal 16+, through the contact shoes 18 and 19, through the short circuiting device, through the contact shoes 19 and 18 to the terminal 16—, thence to the compressor motor, starting the compressor, and restoring the air pressure in the main reservoir. Assuming the governor to be set to operate at a pressure of from 60 to 70 lbs., or in other words, to start the compressor when main reservoir pressure has fallen to 60 lbs., and to stop the compressor when the pressure in the reservoir has risen to 70 lbs.

After the pressure in the main reservoir has been brought up to 60 lbs. or more, the air pressure in chamber A, which is in direct communication with the main reservoir through suitable piping will also have been raised to this point. This pressure in chamber A acting against diaphragm 6 will overcome the pressure of spring 12, thus allowing diaphragm 6 to move upward, and force exit valve 8 to seat on diaphragm keeper 9, thereby cutting off communication between chambers F and D.

Any further increase of pressure in chamber A acting against diaphragm 6 will cause greater pressure to be brought to bear on exit valve 8 and its seat, which insures the proper seating of the valve.

As soon as the main reservoir pressure has reached 70 lbs. the force acting on the under side of valve 5 in chamber A will have overcome the pressure of spring 13, allowing air to pass across the seat to valve 5 and into cavity B, and by reason of the greater increased

area of the valve when exposed to pressure in chamber B the valve will instantly move to its upward limit of travel, thereby establishing communication between the main reservoir and the main piston chamber I by way of chamber A, cavity B, passageway H, and port J.

As the main piston 4 is somewhat retarded in its movement upward by spring 14, it is obvious that some air will by-pass the piston by the way of the leak holes O and O, which, entering chamber K passes through port L to passageway M and discharges directly across the faces of contacts 18 and 19 through ports N and N. This blast of air continues until the main piston reaches its upward position and is seated against seat 20. The compressor circuit will by this time have been broken.

After the main reservoir pressure has been reduced to 60 lbs. or thereabouts, the tension of spring 12, with the assistance of the air pressure in passageway E, will have overcome the air pressure in chamber A acting against diaphragm 6, allowing exit valve 8 to move downward, thereby connecting chamber F with the reservoir by way of chamber A, cavity B, passageway C, chamber D, and passageway E.

It will be readily seen that when the exit valve 8 is open, pressure will soon be raised in chamber F, as the area of the opening around exit valve 8 is greatly in excess of that of exhaust port G. When the pressure in chamber F has been raised sufficiently, together with the assistance of spring 13, to overcome the pressure acting against the lower side of valve 5, it will promptly move down, thereby cutting off communication between the main reservoir, chamber I, and cavity B. Air pressure will then pass from chamber I through J and passageway H, cavity B, passageway C, chamber D, passageway E, and chamber F, through the exhaust port G to atmosphere.

After the pressure in chamber I has been reduced sufficiently, spring 14 will move the main piston 4 from its seat, thus allowing the remainder of the volume of air in chamber I to escape by way of the leak grooves O and O through the piston chamber K, and ports N and N; the spring will then move the piston promptly to its bottom position, thereby closing the motor circuit.

In connection with the operation of this governor it will be noticed that it will be impossible to secure a higher pressure than that at which the governor is set to operate at, as the high pressure, or pilot, valve is identical in operation to that of a safety valve, and when this valve is forced off its seat, air is admitted directly to the piston chamber, thus forcing the piston to its uppermost position and breaking the motor circuit.

INSTALLATION.

Fig. 63. Strainer for Type "A" Governor.

In installing this governor it is preferable to place it inside of the car or at some point where it will be kept warm during the winter time. However, this is not absolutely necessary. Care should be taken in making the pipe connections between the reservoir and the governor so that all pipe is free from scales or other foreign matter. A strainer filled with curled hair is provided for use in connection with this governor. This should preferably be placed close to the governor. Before starting, the contacts should be inspected to see that their adjustment is perfect.

Should the governor not be adjusted for the required pressures, the best results will be secured by unscrewing

adjusting screw 10 so that the pressure will be taken off spring 12. Pressure on spring 13 should be in-

Fig. 64. Governor Completely Dismantled.

creased by means of the adjusting screw 11 until the air pressure, in the judgment of operator, will be higher than that at which the governor is desired to cut-out at.

The compressor may then be started by closing the main switch. When the pressure in the main reservoir has reached the desired point the compressor should be stopped, and adjusting screw 11 turned back until the pressure on spring 13 has been sufficiently reduced to allow the valve to unseat, and the governor to cut out. The pressure should next be reduced in the reservoir to the point at which the governor is desired to cut in at, when pressure may be increased on spring 12 by means of adjusting screw 10 until the governor cuts in. This will bring the range within two or three pounds of that desired, and final adjustment may then be made. After the adjusting screws have been set to the required pressures, the lock nuts 22 should be set up so as to prevent the adjusting screws from coming loose.

THE BRAKE CYLINDER.

The brake cylinder is provided with a hollow rod, and a loose push rod, and cross head which makes it possible to apply the hand brake without moving the piston, thus avoiding unnecessary wear and a useless expenditure of force.

Fig. 65 is a side sectional view of the brake cylinder 2 of National air brake equipment, in which 3 is the piston, and sleeve in which the push rod connected with a system of brake levers is inserted. 4 is the no pressure cylinder head, 5 is the pressure head, in which are two one-half inch pipe tapped holes, to one of which is connected the air piping, the other being closed by a plug 14. The pressure head is bolted to the cylinder by bolts 11, and the joints are made air tight by the use of a rubber gasket 12. The piston follower plate 6 clamps the

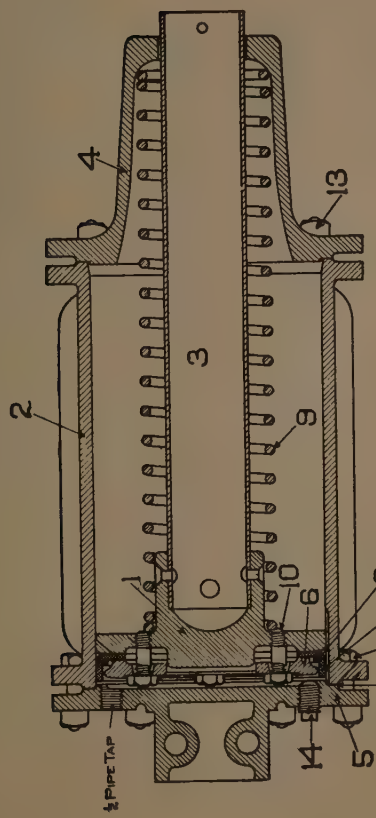


Fig. 65. Diagram of Brake Cylinder.

packing leather to the piston by means of studs and nuts 10. The packing leather 7 is pressed against the cylinder wall to prevent air escaping past the piston. A round spring packing expander 8 serves to hold the flange of the packing leather against the cylinder walls. A plain pressure head is generally provided, which is fitted with a detachable lever bracket in order that the slack adjuster may be used or not, as desired, or the slack adjuster may be attached at any time without requiring a new cylinder head, or any other change, except removing the detachable bracket, and putting the slack adjuster in its place.

INSTALLATION OF THE BRAKE CYLINDER.

If the brake cylinder is 10 inches or less in diameter, it should be bolted to a hard wood plank not less than 2¼ inches in thickness, and 12 inches wide, and long enough to fasten it securely to the car body framing. Bolts smaller than ¾ inch should not be used for 10 and 12 inch brake cylinders, and for the 14 inch brake cylinder ⅞-in. bolts should be used, and the plank support should be of proportionally increased strength. The position for the brake cylinder should be so selected in its relation to the foundation brake rigging, that a release of brakes will force the push rod to the bottom of the hollow piston sleeve. It is advisable to place a union in the pipe connecting it to the train pipe, at a convenient point on one side of the cylinder, to enable the head to be removed for cleaning the cylinder.

In removing the cylinder head for cleaning, the piston should first be forced outward by a slight application, and a nail or piece of wire inserted in the hole provided

for that purpose in the piston rod pipe, to prevent the spring from forcing the piston out when the cylinder head is removed.

INSPECTION AND MAINTENANCE OF THE BRAKE CYLINDER.

All lint and other matter which might possibly collect should be scrupulously cleaned from the piston and cylinder, and caked up deposits of oil and grit should be carefully cleaned out of the leakage groove. The packing leather, expander ring, and piston should also be thoroughly cleaned. The packing leather should be kept soft and pliable, so that it will have a tight fit with easy action in the cylinder; to this end a space between the leather and the follower should be filled with a light grease. The use of a light grease in the cylinder has been found to give better results than oil. The use of too much grease should be avoided as it tends to thicken and interfere with the easy working of all parts. The follower nuts should be frequently tested for looseness.

The Committee on Recommended Practice of the American Air-Brake Association (13th Annual Convention, June, 1906) advises that brake cylinders be cleaned and cared for as follows: 1. The brake cylinder need not be removed from the car for cleaning; first, secure the piston rod firmly to the cylinder head, then after removing the cylinder head, piston rod, piston head and release spring, scrape off all deposits of gum and dirt with a narrow putty knife or its equivalent and have the removed parts wiped with waste saturated with kerosene or other light oil. 2. The packing leather should never be permitted to soak in kerosene oil, as the penetrating qualities of kerosene reach into the pores of the leather

and force out the life-giving qualities of the special oil with which the leather is treated by the manufacturer. 3. The expander ring to be of a circumference which shall fit the bore of the brake cylinder when the ring is removed from its place between the follower and packing leather and entered in the cylinder. 4. A goodly quantity of grease should be placed on the expander ring and the adjacent side of the packing leather, thus permitting the pressure to force the grease into the leather and giving it greater life. 5. No sharp tool to be used in getting the packing leather into the cylinder. 6. After the piston is in place, and before the cylinder head is fastened on, the piston rod should be slightly rotated in all directions about three inches from the center line of the cylinder in order to be certain that the expanding ring is not out of place.

THE RESERVOIR.

The reservoir is the receptacle in which the compressed air is stored. It should have a capacity sufficient to supply the air necessary for three or four applications of the brakes without a reduction of more than twelve or fifteen pounds in the reservoir pressure. It is also of considerable importance to have a reservoir as large as possible on the car, as this will result in considerable saving in the cost of maintenance of the motor compressor. Too small a reservoir will cause every ordinary application of the brakes to start the compressor into action. Such constant starting and stopping will result in unnecessary wear to both compressor and automatic governor.

The weight of the car determines the size of brake

cylinder to be used, which in turn governs to a large extent the capacity of the reservoir. The use of the following sizes of reservoirs is recommended, the dimensions given being over-all.

For 8″ cylinder.....16″ x 45″
For 10″ cylinder.....16″ x 48″
For 12″ cylinder.....16″ x 60″

While the above sizes of reservoirs are considered standard, other sizes can be furnished when required.

Since the function of the reservoir is also to entrap any water, oil, or dirt which may be swept in by the compressed air, thus preventing it being carried further into the brake system, it should be drained every day. The drain cock should be left open while the car is in the barn so that every trace of oil and water may be removed from the air storage space.

The reservoir is constructed of highest grade ¼-inch steel tubing, designed to afford the maximum strength, with a minimum weight.

The shell of the reservoir is made in one piece with overlapping seams which are firmly riveted together and rendered perfectly air tight. The ends of the reservoir are pressed in and beaded over to form a joint which is afterwards made absolutely tight by brazing.

At one end the reservoirs are tapped to receive the pipe connections to the compressor. They are tapped at the other end for the reception of the main reservoir pipe leading to the motorman's valve. A tapped hole is also provided for the connection to the air compressor governor. The points where these pipes enter are heavily re-inforced.

INSTALLATION OF THE RESERVOIR.

The main reservoir should be well secured directly to the car body by means of the Reservoir Cradle, which consists of U-shaped iron bars and hardwood cleats, which are bolted to the car body beams, either with long screws or through bolts. The cleat or plank is hollowed out so as to fit the curvature of the reservoir properly; the drain cock should always be placed downwards.

Fig. 66. Air Gauge.

AIR GAUGES.

On straight air brake equipments the single hand gauge, which indicates the pressure in the main reservoir only, is standard practice. It is not only much cheaper than the duplex gauge, but since an experienced motorman does not set the brakes according to gauge pressure, but depends principally upon his own judgment, the use of a duplex gauge is not essential.

INSTALLATION OF AIR GAUGES.

The pressure gauges should be placed within convenient sight of the motorman. The exact location depends largely upon local conditions. Sometimes the gauge is placed overhead, attached to the roof of the motorman's cab, directly above the brake valve. The single hand gauge is always connected to the main reservoir pipe. One-quarter inch pipe should be used. The duplex gauge is provided with two standard one-quarter inch nipples, one for main reservoir pipe and one for the train pipe, respectively, with a corresponding red hand for main reservoir pressure, and the black hand for train pipe pressure. In case illuminated gauges are used, the pipe connections are the same as described above, but a wire connection is made to the lamps of the gauge, which are usually connected in series with five of the standard 110 volt on a car where 550 volts are used.

PIPING.

The reservoir pipe connects the reservoir with the motorman's valve, and is constantly subject to reservoir pressure. Cut-out cocks should be placed in this pipe, by means of which the reservoir may be cut off from the operating valve whenever it becomes necessary to examine or remove the latter. Ordinarily the pipe connection for the main reservoir is one-half inch, being merely a continuation of the supply pipe. The train pipe extends from the motorman's valve, to the brake cylinder.

When trailer cars are used, a cut-out cock with flexible coupling is used at each end of the car, in order that the

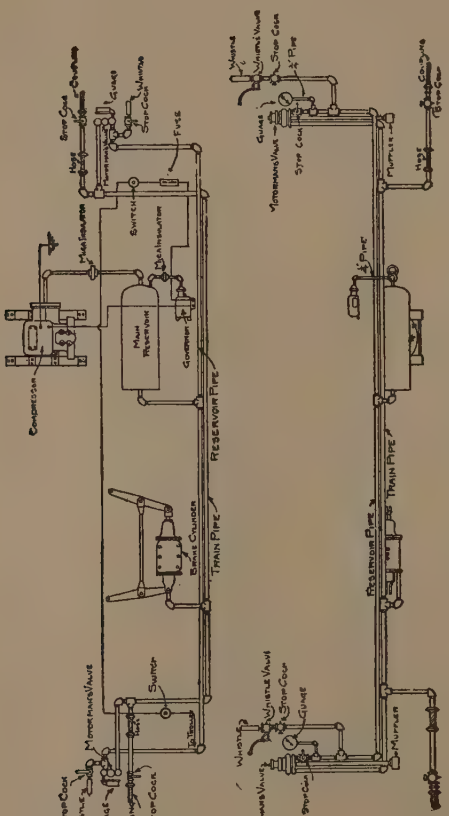


Fig. 67. Piping for Motor Car.

admission of reservoir pressure to the train pipe will send air to both the motor and trailer brake cylinders. Generally the train pipe connections are one half inch pipe, but for service where a number of trailers are used, this pipe should be three-quarter inch, or one inch in diameter.

The reservoir pipe connects the discharge opening of the compressor to the reservoir, and is always subject to the reservoir pressure. The pipe connection from the compressor to the main reservoir is three-quarter inch for the A-1, A-2, and A-4 compressors, and one inch for BB-2, BB-4, CC-3 and DD-4 compressors, and is provided with insulation joint and union. The insulating joint should be located as closely as possible to the reservoir, and should be placed in as nearly a vertical position as possible, and at the opposite end of the reservoir to the pipes leading to the motorman's valve and governor. The governor pipe connects the main reservoir to the automatic governor. For the governor pipe, standard one-quarter inch pipe should be used, except in service where several trailers are used, when one-half inch pipe should be employed. An insulating joint is inserted in the pipe near the governor, which completely insulates the governor from any of the pipe which might become grounded.

Long bends should be used whenever possible, to avoid friction losses. When bends must be made, the piping should be thoroughly blown out with steam, or air pressure before the pipe is put into service. All joints should be threaded with sharp dies, and the joint made with a good grade of shellac or japanned bronze applied to the male thread only. Tinning in molten solder may also be used. With proper care, a bottle

tight joint is easily made. After connecting up all piping, full pressure should be pumped up in the reservoir, with the motorman's valve at release position. All piping should be hammered, and blown out, after which maximum pressure should be pumped up in the reservoir, and tests for leaks made at the joint, and cut-out cocks. This may be done by applying soap suds. The piping should be installed in such a manner that there will be no sags, or pockets in which moisture might collect, and freeze. Care should be exercised to firmly clamp all piping to the car in order to prevent vibration thereby causing leaks to occur.

WIRING FOR MOTOR COMPRESSOR OUTFITS.

The wiring connecting the main trolley circuit with the motor compressor should be installed with special precautions to avoid any possibility of grounds developing after the car has been in service for a time. This wiring should be connected to the trolley wire at a point just inside of the location of the lightning arrester. As far as practicable the wiring should be run inside of the car, substantially cleated in place, and should always be so located that there will be no danger of injuring it when the car is being jacked up. Where the wiring is exposed underneath the car, or runs over iron, it should be covered with a good rubber tubing.

The size of solid rubber covered wire used should be No. 12 B. & S. for A-1, A-2 and A-4 compressors, and No. 10 B. & S. for BB-2, BB-4, CC-3 and DD-4 compressors, when operating on standard railway voltages. Although smaller sizes of wire may be used without causing dangerous overheating, or heavy drop, they are too weak mechanically.

While the relative arrangement of the various parts of the equipment is fully shown in the diagram (Fig. 68), the position at which the compressor circuit is to be connected to the trolley line must be decided on in each individual case. If the connection is made to the trolley line outside of the main switches, many advantages re-

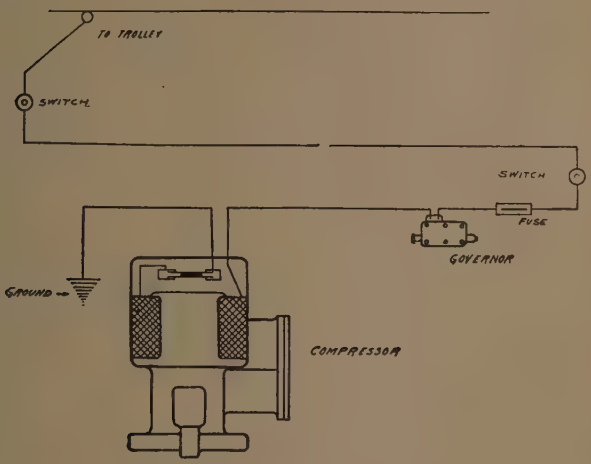


Fig. 68. Wiring Diagram.

sult, such as, for instance, preserving the electrical continuity of the compressor circuit, should blowing of the main fuse occur, and current may be had in the compressor circuit when it is not desired on the controller. If connection for the motor compressor is made between the first main switch and the point where the light circuit is connected a very effective lightning arrester is made

when the lamps are turned on during an electric storm, but a special arrester for the motor circuit will compensate for its slight extra cost as a protection to the compressor.

Fig. 69. Snap Switch.

The compressor switches should be located within convenient reach of the motorman without requiring him to move out of his normal position. The partial enclosure of main switch under a shelter is recommended as a protection against rain, meddling by passengers or becoming caught by the trolley rope.

The main switches are single pole, double break, snap switches of the indicating type "On and Off," which slide behind a screen on the front of the cover and show whether the circuit is made or broken.

FUSE BLOCK.

The fuse block or base (Fig. 70) is made of a special grade porcelain and may be placed in a convenient and accessible point between the main switch and the gover-

nor. It should be easily accessible with a screwdriver; the point selected should also be dry and free from any danger of ground connections.

The fuse supplied is of the non-arcing type, fitted with a small wire on the outside to indicate whether the fuse has blown or not. The fuse block is provided with bayonet clips so that the fuse proper may be readily placed in position.

Fig. 70. Fuse and Base.

MOTORMAN'S VALVE.

Fig. 71 shows this valve with sander attachment. Fig. 72 is a phantom view of the valve, showing to some extent the interior arrangement of the parts.

Referring to the sectional drawing (Fig. 74) the appliance consists essentially of a sliding valve, 6, with ports on its lower face so arranged that they register at the proper time with suitable ports in the valve seat, 2, to make the necessary connections for the desired braking applications. The valve seat contains three ports which connect with the main reservoir, brake cylinder and atmosphere respectively. The slide valve, 6, is manipulated by turning the eccentric spindle or stem, 4, by means of the removable handle, 7, which fits over the

end of the valve stem at the opposite end of the eccentric; this handle moves through an arc of about 120° in turning from release position at the extreme left, to emer-

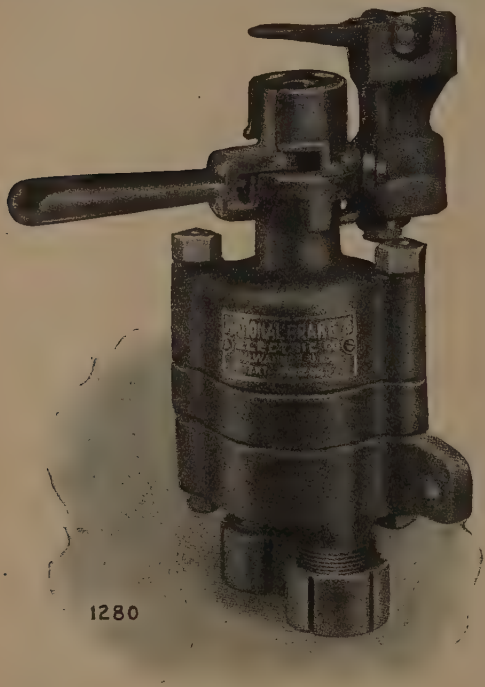


Fig. 71. Motorman's Valve with Sander Attachment.

gency position at the extreme right. It is provided with a latch, 8, which engages with the notches in the top plate.

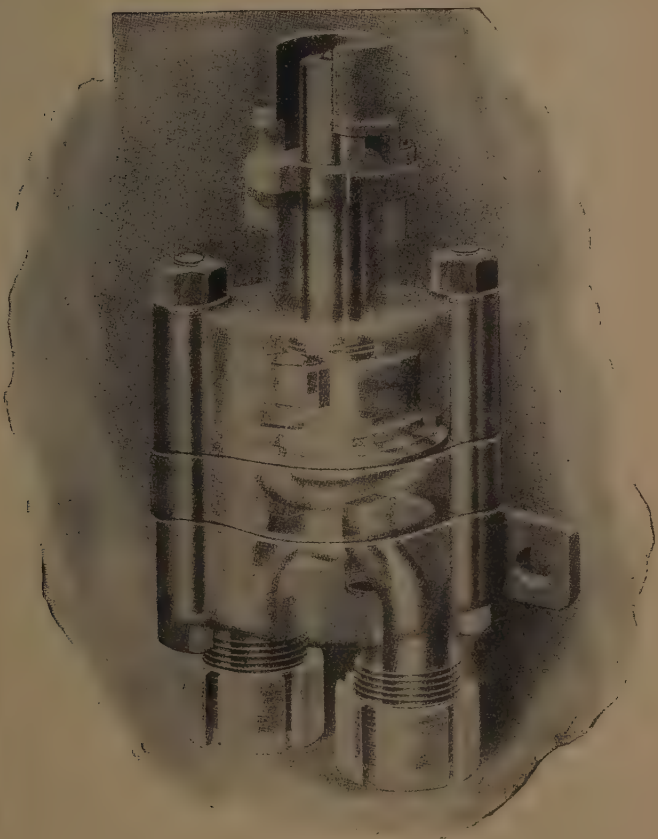


Fig. 72. Motorman's Valve. Phantom View.

The handle can only be inserted or removed when the valve is in "lap" position, and the ports are blanked so that there is no connection whatever between any of the

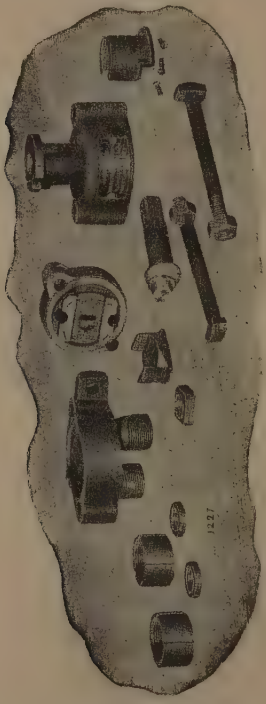


Fig. 73. Brake Valve with Parts Separated.

three ports in the valve seat. When the handle is removed the mechanism is securely safeguarded from tampering by passengers, by a protecting shield, 20, fitted

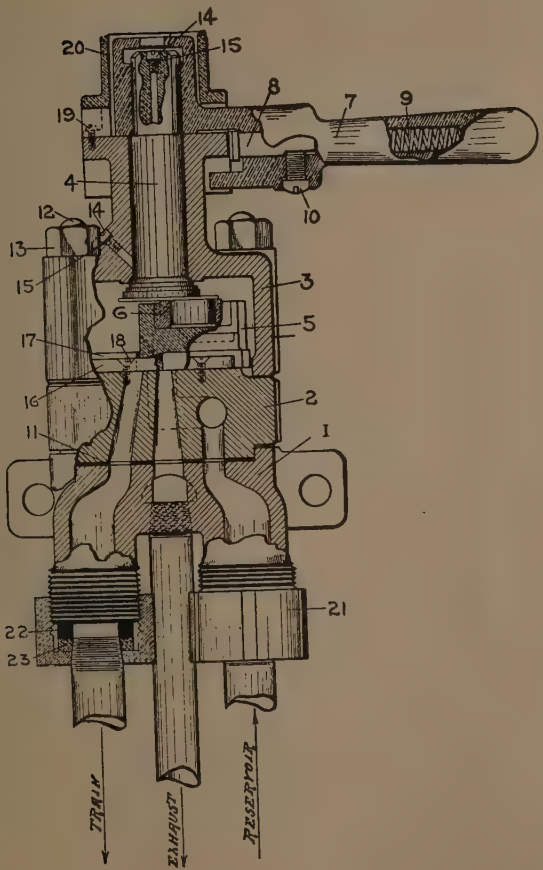


Fig. 74. Sectional View of Motorman's Valve.

over the valve bonnet, 3, which prevents operation of the valve without the handle provided for that purpose. On the left side of the bonnet near the valve seat is located an oiling orifice which has a screw cover, 14, and a gasket, 15. The shaping and proportioning of this oil cup is such that it will contain sufficient oil for over 150,000 applications of the valve.

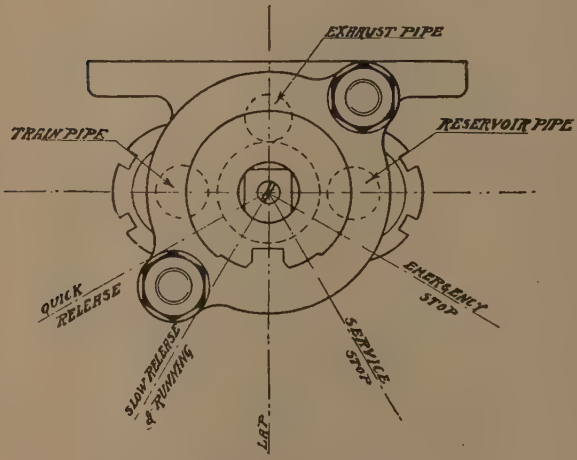


Fig. 75. Positions of Operating Handle.

The design of the sliding valve is such that it wears itself into position, adjusting itself to a proper seat without attention or repairs. The valve bonnet is screwed to the face, 2, by the Tee bolts, 12, which are fitted with nuts, 13. Fig. 75 illustrates the various positions of the handle corresponding to the registration of ports in the sliding valve and its seat. With the handle at the

extreme left, the positions and operations that occur in moving the handle through its successive steps are as follows:

QUICK RELEASE, OR EMERGENCY POSITION.

An unobstructed passage, or port, in the slide valve provides a connection between the train line and atmosphere through the slide valve. In this position a very quick release of brakes will occur, due to the discharge of air through a large opening.

Fig. 76. Valve Entirely Dissected.

RUNNING POSITION AND SERVICE RELEASE.

The brake cylinder is connected to the atmosphere through an opening of restricted size in the valve seat, which gives a graduated release of the brake. A spring actuated pawl arranged directly in the handle comes in contact with an offset on the motorman's valve cap, and defines this position. The operating handle should be placed in this position when the car is running down grade, and the motorman has admitted a trifle too much air in the brake cylinder, thereby giving a slightly too

strong an application of the brakes, and decreasing the speed of the car more than desired. By moving the handle to service release position, the brakes may be partially released by exhausting a small quantity of air, which reduces the pressure, while still retaining a considerable pressure in the brake cylinder when the handle is thrown back to lap position. This position is also employed in stopping the car, by gradually reducing the pressure in the brake cylinder as the speed is reduced. This will give a smoother and more agreeable stop than if all the pressure is retained until the car comes to a dead stop.

POSITION THREE, LAP POSITION.

When the handle is moved to this position all ports in the valve seat and in the sliding valve are blanked so that there is no connection between any of the three ports in the seat; in this position only can the valve handle be removed. This position serves several purposes, the most important of which is that removal of the handle renders the valve neutral. It is also possible to apply the brakes with this valve, then move the handle to lap position, take it to the other end of the car and release the brake with the valve on that end.

POSITION FOUR, SLOW SERVICE APPLICATION.

With the handle in position for service stop, a connection through a graduated port area is made from the main reservoir, and air under pressure is admitted gradually into the brake cylinder, thereby making a gentle stop with just enough air to accomplish the work. This

position is determined in a similar manner as the position for running and slow release application previously explained. The area of the admission openings in the National improved motorman's valve have been considerably increased over formerly made types to meet the demand for quicker application of brakes due to heavier cars and higher speed. A long and narrow triangular shaped groove has been made in the admission orifice to graduate the admission of air, which in most types of valves is admitted too suddenly.

EMERGENCY APPLICATION.

In this position the large and unobstructed port connects the main reservoir to the brake cylinder, allowing maximum pressure to apply full braking power almost instantaneously. Such application should never be made except in dire necessity. When making an emergency stop the rails should be sanded in order to obviate all possibility of sliding wheels, with a consequent bad stop.

INSTALLATION OF THE MOTORMAN'S VALVE.

The motorman's brake valve should be attached to the vestibule framing, or dash rail, by means of the bracket for the stud and nut attached to the back of the valve for that purpose. Its position between the controller and hand brake should be such that the motorman can readily rest his hand on the handle when in lap or release position. The margin of space between the brake handle and controller should be sufficient to permit movement of the operating handle throughout its entire range without interference.

The best height for mounting the motorman's valve is usually from 36 to 42 inches from the platform to the handle. In general the valve can be mounted on a hand-rail on an open end car, and at a convenient height in a vestibuled car. The lower end of the valve is provided with three openings, two of which are equipped with unions for half-inch pipe. The one on the right in front, marked R, connects to the main reservoir pipe, and the one on the left in front, marked T, connects with the train pipe. The third opening in the rear, marked E, nearest to the supporting stud, is for the exhaust pipe to atmosphere. A pipe is connected to this last opening of such length as to extend beneath the platform, and if the noise of escaping air is objectionable, a muffler should be employed. A piece of pipe extending back under the platform of the car some six or eight feet is generally sufficient to suppress the noise.

The branches for the train pipe and main reservoir pipe are provided with union spanner nuts and brass ferrules; the latter should be screwed on to the end of the pipe until the pipe is just flush with the other side of the ferrule, which should be sweated on with solder. The end of the pipe should then be filed off even with the ferrule to form a smooth face for the union gasket and to ensure a good joint.

MAINTENANCE OF THE MOTORMAN'S VALVE.

The motorman's valve should be taken apart and cleaned carefully in gasoline at intervals, depending on the severity of the service. The oil pocket in the valve contains a sufficient supply to allow about 150,000 applications of the valve, which is ordinarily equivalent to

six months of service. The sliding valve and its seat should be covered with a special grease of light body and minimum density. The slide valve is made with an oil reservoir in the upper side. Four small holes lead down from this reservoir to the valve face. These holes are located so that they are never uncovered by the ports,

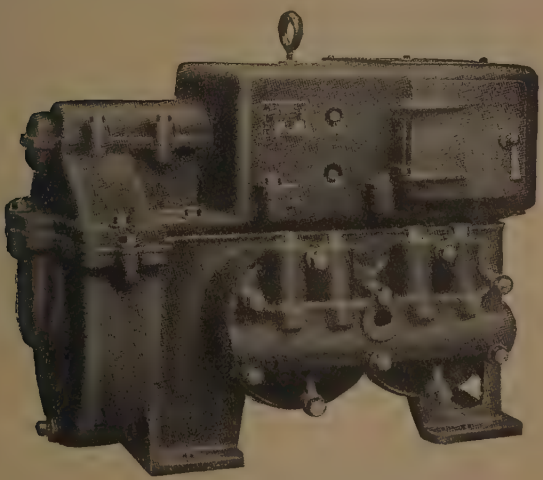


Fig. 77. Type CC-3 Compressor.

with the result that the oil is fed down from the reservoir only in a sufficient quantity to keep the valve seat well covered. To fill the reservoir, a small hole is drilled through the entire length of the valve stem. Oil poured in at the top of the stem drops directly into the reservoir. The stem itself is oiled through an opening in the side of the casting enclosing it.

The difficulties of regrinding the seat, should it become necessary, are obviated by screwing the guides to the seat casting, instead of having them an integral part of this casting. On removing these guides the valve seat extends out beyond any other part of the casting, and this permits the seat to be surfaced in a lathe. To prevent the valve being placed on the seat in a reversed position one of the guides is made slightly higher than the other, so that the valve will not seat properly unless placed in the right position.

THE NATIONAL TYPE "C" SANDER VALVE.

A feature which is of the greatest importance in obtaining proper operation of the air brake, assuring the greatest possible negative acceleration of the car, and at the same time preventing the wheels from skidding with the consequent formation of flats, is the proper sanding of the track. This can be accomplished in the most economical way by the National Pneumatic Track Sanding Valve, which is designed to be fitted to the motorman's valve.

The arrangement of the track sanding valve directly above the motorman's brake valve, as shown in Fig. 71, permits the motorman to apply sand to the track exactly when it is needed; and thus it will be evident that besides assuring a positive smooth stop, it also prevents the extravagant and wasteful use of sand, which it is impossible to avoid with the majority of track sanding devices. Though this feature may at first appear of little importance, the element of cost is the least important to be considered, for many times a very serious accident may be avoided if sand is available to assist the brakes; it

is well known to all railway officials that many serious accidents in the past have resulted from a lack of sand at the critical moment.

NATIONAL EMERGENCY VALVE.

The National emergency valves are designed to eliminate the deficiencies of the straight air brake system by giving to it the automatic feature in case the cars in a train become separated, and also by placing the control of the brakes in the hands of the conductor, as well as in the hands of the motorman. It is claimed that these valves give all of the advantages of automatic air, with but few of its complications.

In the sectional view of the emergency valve, Fig. 78, the body, 1, which is made of cast iron, encloses the operating parts of the valve and contains the three main ports, and the auxiliary port which connects with the main reservoir, auxiliary reservoir, the train pipe line and the emergency pipe line, as well as with the brake cylinder. The auxiliary reservoir is connected with the slide valve chamber and the main reservoir with the piston chamber.

The slide valve, 6, controls the three ports; the one to the left leads to the brake cylinder, the middle one is connected to the train pipe line and the port on the right connects with the emergency line. The drawing shows the valve in normal position for straight air operation. Pressures in the auxiliary and main reservoirs and in the emergency pipe line are equalized through the small port shown to the right of the slide valve, and the piston, and valve are held in position shown by the spring, 10, which exerts a pressure of about 15 pounds per square inch on the back of the piston.

The piston, 5, and the slide valve, 6, work in air chambers which are lined with special bushings, 3 and 4. The piston and the piston rod consist of the same casting, which also secures the spring cap, 7, in position. The spring, 10, is adjusted by the flat-headed screw, 19, which in turn is locked by the hexagonal nut, 20. The

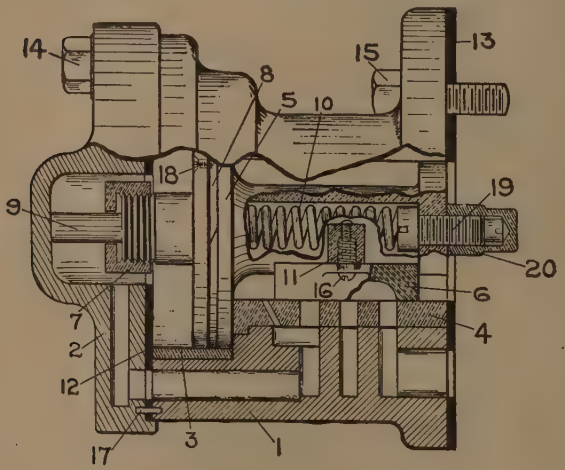


Fig. 78. Sectional Diagram of Emergency Valve.

piston buffer, 9, is provided with a cover, 2, which is secured to the body, 1, by screws, 14. The piston is fitted with a packing ring, 8. The small set screw, 18, is used only when the emergency valve is applied to trailer cars. It is omitted when the valve is used on motor cars. The small set screw, 16, and spring, 11, keep the valve against its seat when there is no air pres-

sure on the opposite side. Both ends of the valve are fitted with special gaskets, 12 and 13, which render it airtight.

With the valve in normal position, air from the train pipe line enters the middle port, passes through the connecting port in the valve, and enters the brake cylinder through the port to the left.

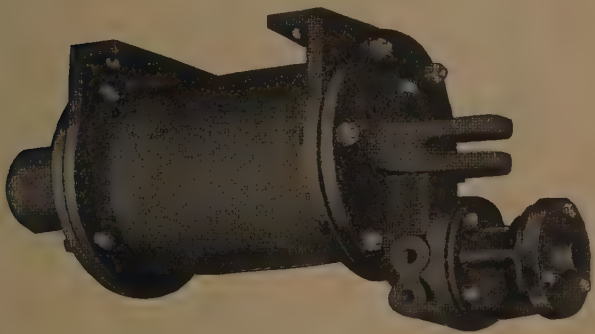


Fig. 79. Valve Mounted on Brake Cylinder.

Should the train separate, or the conductor pull the emergency valve, air escapes from the emergency line, and the pressure behind the piston is reduced. This causes the piston and valve to be pressed to the right by the auxiliary reservoir pressure in the slide valve chamber. When this occurs, 1. The port to the brake cylinder is uncovered and opened to the slide valve chamber, and as this chamber is connected to the auxiliary reservoir, the brakes are set by the equalization of pressures in the auxiliary reservoir, and the brake cylinder. 2. The train pipe line is connected direct to the emergency pipe

line from the slide valve, and the emergency pipe line is given an additional opening to the atmosphere. 3. This small port to the left of the valve seat is covered by the valve, and air is prevented from passing to the emergency line from the auxiliary reservoir. 4. The connection between the main reservoir and emergency line is cut off by the seating of the small screw hole in the piston, so that no air can pass into the emergency line from the main reservoir. To release the brakes after they

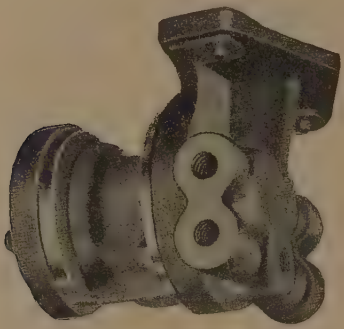


Fig. 80. Valve Mounted on Bracket.

have been set by the reduction of pressure in the emergency line, the openings of this line to the atmosphere are first closed, and the motorman's valve moved to emergency position; air then passes from the main reservoir through the motorman's valve and train pipe lines into the emergency pipe line, which is connected to the train pipe line through the port in the slide valve. The increase of pressure in the piston chamber, which is connected to the emergency pipe line, and the pres-

sure of the spring previously mentioned, cause the piston and valve to move to their normal position. When this occurs, the motorman's valve may be thrown to release position, and the brake cylinder will be vented to atmosphere through the train pipe line, at the same time the connections are reëstablished between the emergency pipe line, auxiliary and main reservoirs, and the pressures in these are equalized.

Fig. 81. Showing Valve Complete and Valve Dissected.

INSTALLATION AND MAINTENANCE OF EMERGENCY VALVE.

The valve should be mounted on the emergency valve bracket, which is located at any convenient point under the car body. If a bracket is not used, a special head is provided on the brake cylinder on which the emergency valve is supported by four cap screws, 15. The piston packing ring should not be removed from the piston at any time. The flat head screw in the piston head is to be used only when the valve is applied to trailers. The hole should be left open when the valve is used on motor cars. In case the valve is separated from the brake cylinder head or bracket, care should be taken to keep the open ports protected from dust and dirt. When installed,

the valve should be operated several times per week as a precaution that it is in proper working order at all times, whether required or not. When used on high-speed interurban cars it should be worked at the commencement of each trip.

CONDUCTOR'S VALVE.

The conductor's valve is used as a safety device, accessory to the emergency valve. The sectional view, Fig. 84, shows clearly the construction of this valve. It consists of a malleable iron body, 1, enclosing the steel valve stem, 2. A retractile steel spring, 3, is fitted in a recess in the lower portion of the cap nut, 4, which is screwed into the valve body. The spring presses against the stem, and holds the valve normally closed. A pull of the cord presses the lever, 5, against the end of the stem, 6, overcoming the resistance of spring, 3, and allowing a small amount of air to be vented from the pipe, thereby reducing the pressure in the emergency pipe line, and causing the latter to perform its function as previously described.

INSTRUCTIONS FOR OPERATING NATIONAL STRAIGHT AIR BRAKES.

The compressor is started by closing the snap switch, which allows current from the trolley circuit to flow through the switch and fuse, thence through the governor, which is automatically closed by the current, then through the motor and thence to ground. The air compressor at once begins to operate and charges the main reservoir. The compressed air flows to the valve seat of

the motorman's valve. The motorman's valve is provided with notches which indicate the position of the handle for the various operations of the valve. While it is a comparatively simple matter for a novice, by pay-

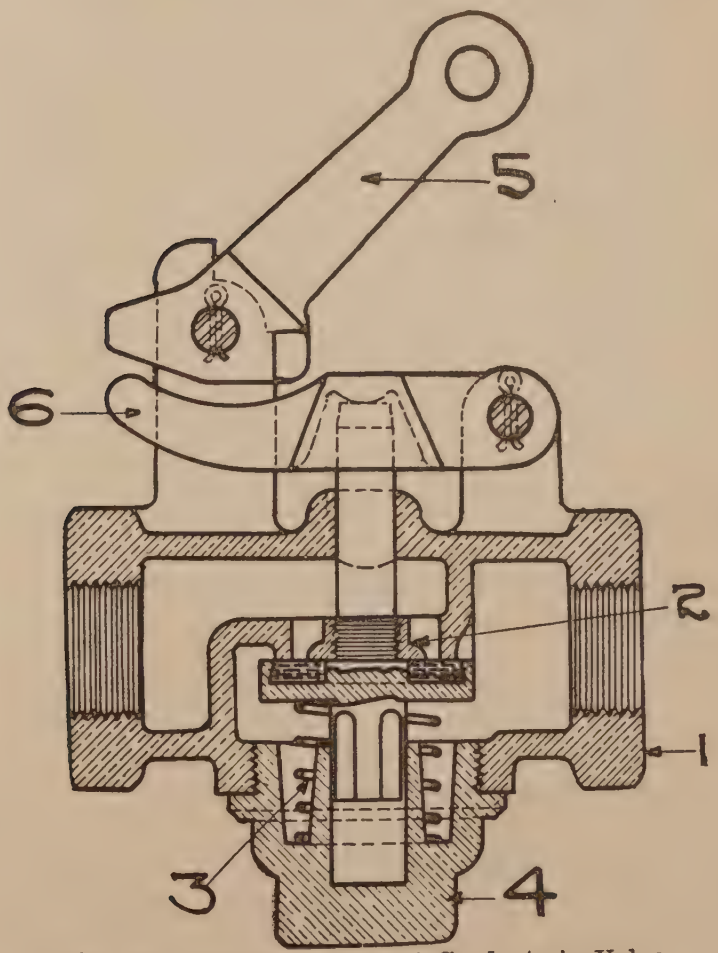


Fig. 84. Sectional View of Conductor's Valve.

ing attention to the notches, to operate the brakes after a fashion, quick, accurate and agreeable stops are only made after some practice. The personal equation enters so largely into the problem of operating brakes prop-

erly and efficiently, that it is impossible for any considerable number of motormen to obtain equal results at the start. The practice which a careless or indifferent motorman may get into of "fanning" the brake handle is a pernicious habit and wastes air excessively, besides causing unnecessary wear and tear on the trucks and all other parts of the equipment.

The operating valve handle must always be inserted at "lap" position, which is readily apparent from the enlargement of the slot in the top plate for that purpose, and withdrawn at the same position, when changing from one end of the car to the other; moving the operating handle to "lap" position causes the ports of the valve to be so connected that air can neither be admitted to or discharged from the brake cylinder. By turning the handle to the extreme left the valve is placed in "full release"; moving the handle to the right as far as the small notch opens the small port, and a further movement to the right opens the large port.

A large quantity of compressed air will issue from a very small opening in a short interval of time, hence to apply the brakes lightly throw the handle to the small notch and immediately move it back to "lap" position. The air previously admitted to the brake cylinder is retained, thus keeping the brakes applied. Partial release of the brakes is effected by moving the handle to "release position" and quickly returning it to "lap," which permits a portion of the air to be exhausted, reducing the pressure in the cylinder.

To secure the quickest possible stop, the maximum pressure which will not cause skidding of the wheels should be applied throughout the stop, and the greater the speed the greater the pressure that may be applied

without causing skidding. The coefficient of friction of brake shoes upon wheels varies from .27 at five miles per hour to about .10 at 60 miles per hour, hence to produce the same retarding effect at 60 miles per hour, about three times the pressure should be applied to the shoes at the higher speed, as could be safely applied at the lower speed.

It follows generally that to stop a car quickly, full operating pressure should be applied instantly, and gradually released as the car decelerates. A smooth and easy stop will also be produced by this method, as the sudden checking of speed which jostles passengers is prevented. To effect a "service stop," therefore, admit from 20 to 30 pounds of air pressure at once when commencing to stop, by partially opening the large port, and release it slowly step by step as the speed falls, retaining about ten or twelve pounds in the cylinder, until the car comes to a full stop. After a short experience a motorman will learn to gauge the distance necessary in which to effect a stop from a given speed, and thus make a smooth and agreeable stop with but one application of the brakes. An intermittent series of applications and releases while making a stop produces an annoying motion of the car, wastes air excessively and is in every sense bad practice.

In making an "emergency stop" apply full pressure, usually 60 pounds, at once, regardless of whether the controller is turned off, then apply sand and slightly release the pressure as the car decelerates.

When the signal to start the car forward is received the handle should be moved to "release" position before power is applied to the car motors. A very common error with beginners is to apply the brakes too strong on commencing to descend a grade. On account of the mo-

mentum of the car, and a certain mechanical inertia inherent in braking systems, the car will not instantly take the desired speed; apply the brakes lightly at first, keep the handle on "lap" notch, and wait a little for the speed to be checked. If then the car fails to slow up, admit a trifle more air and if the grade is long, continue the operation (if necessary) until off the grade.

In putting a car in the barn or leaving same, the hand brake should always be set up to prevent persons from meddling with cut-out cocks. In taking a car from the barn first see that all the cocks are accurately set, and that there is sufficient air in the reservoir. Place the handle of the operating valve in position and move it around to "emergency," then back to "release" to be sure that it works freely. To feel sure that wrong connections have not been made, test the brakes for operation both in "service" and "emergency" positions; if these tests are satisfactory, and the proper pressure is supplied to the brakes, they may be depended upon to work properly.

MAKING UP TRAILERS.

In making up trains much care must be exercised in connecting hose couplings, so that there will be no escape of air. Open all cut-out cocks, excepting those on the rear of the last car and on the front of the motor car. These must be closed.

Before uncoupling the cars, close the cocks, and disconnect the hose before taking out the drawbar pin.

PISTON TRAVEL.

In air brake practice there are several terms used in connection with the travel of the piston: 1. The Standing Travel is the distance the piston is forced outward in setting the brakes upon a car at rest. 2. Running Travel is the length or distance the piston is forced out when the brakes are set upon a moving car. The running travel always exceeds the standing travel on account of the flexibility in brasses, the downward pull of the shoes upon the wheels, the play between boxes and pedestals, and to all the various factors which act to increase the lost motion in the brake rigging under the action of the car motion. Running travel is generally about 1½ inches greater than standing travel. 3. False Travel is an abnormal length of piston travel caused temporarily by faults in track construction, or other unusual stresses which may occur when the car is in motion.

The effect of a short piston travel is to cause a greater brake cylinder pressure, with a given reduction in train pipe pressure; for instance, a 15-pound reduction in train pipe pressure gives a brake cylinder pressure about 40% higher with a 5-inch than with a 10-inch piston travel.

To adjust piston travel so that there will be a very uniform setting of the brakes on each car, it is necessary to employ an automatic slack adjuster. When this device is not employed, the best practice is to make the standing piston travel six inches.

Uniformity of piston travel upon the several cars in a train is of highest importance. Excessive length of piston travel causes a reduction in the brake cylinder pressure, with a proportionate lowering of efficiency.

Moreover, a greater consumption of air is brought about, which necessitates more frequent action of the compressor, and hence increased wear and strains. Exceedingly short length of piston travel will result in a dragging action of the brake shoes upon the wheels when the brakes are released; also there is danger of excessive brake cylinder pressure, which causes skidding of the wheels when the brakes are set.

A correct piston travel is obtained when there is just enough brake shoe clearance on release of the brakes. This length of travel is ordinarily six inches, as previously stated.

THE ENERGY CONSUMED IN BRAKING.

The amount of energy stored in a moving train which must be dissipated by the brakes, is sometimes quite large. The kinetic energy of a moving body is represented by the equation $E = \frac{1}{2}$ M.V.^{2}. Where E = the energy expressed in foot pounds, that is the number of pounds raised one foot in one minute. M = the mass of the train (its weight in pounds) or w $\div$ g where g = the acceleration due to gravity, which is 32.2 feet per second. V = velocity in feet per second.

Miles per hour $\times$ 1.47 = the feet per second.

To absorb this energy and bring a moving train to a stop, it is necessary to exert a force f over a distance d, which is expressed as e = p $\times$ d where p = pounds pressure applied to the brakes, d = distance in feet passed over before the speed becomes nil.

If we substitute for m in the preceding equation its equivalent $\frac{w}{g}$, both equations become equal to each other.

Therefore, $D = \frac{w\,v^2}{2\,g\,f.}$

Example:—A 40-ton car must be stopped from a maximum speed of 30 miles per hour on a perfectly straight track. In what distance will it come to a stop if the train resistance due to friction, wind pressure, etc., is 20 pounds per ton and the braking force applied is 280 pounds per ton?

$$D = \frac{40 \times 2000 \times (30 \times 1.47)^2}{2 \times 32.2 \times 300 \times 40} = 268 \text{ feet.}$$

NATIONAL A. C. D. C. AIR BRAKE APPARATUS.

The advent of the single phase electric railway system, and the adoption by numerous electrified sections of existing steam railroads of single phase alternating current as motive power has necessitated radical changes from former standards in the car and other equipment, including the air brake apparatus, more specifically the motor compressor and the governor for same.

The present tendency toward operating the interurban lines on single phase circuits, and running the cars into the heart of the city over the direct current city lines necessitates the building of apparatus of such design and construction as permits of its operation on both the direct, and alternating current circuits. The fundamental characteristics to be taken into consideration in designing single phase air brake apparatus are high efficiency, serviceability, and absolute reliability and freedom from breakdown at all times. To meet the exacting conditions of service required by modern high speed single phase electric railway operation the National Brake & Electric

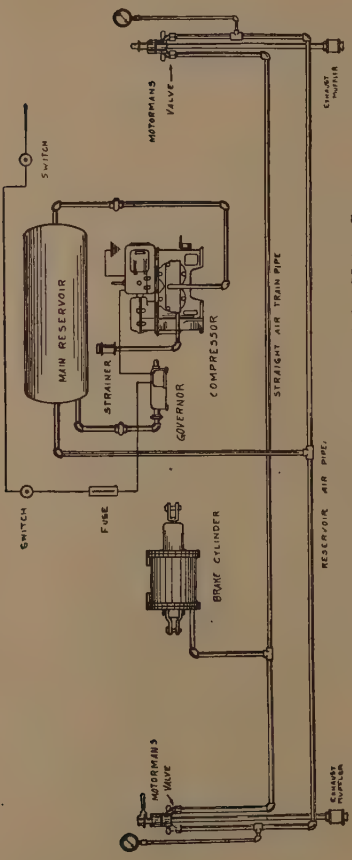


Fig. 86. Straight Air Brake Equipment for Motor Car.

Company has developed and perfected a class of apparatus that compares most favorably in all respects with its well known direct current air brake equipment.

THE COMPRESSOR.

The A. C. D. C. type of motor compressor manufactured by this company is the result of years of serious study, careful experimental work, and a thorough and intimate knowledge of the conditions and requirements of the electric railway braking art in its present day state of perfection.

The compressor, in general appearance, resembles closely the company's standard direct current machine, and is also of the entirely closed type, as may be seen by referring to Fig. 74. The motor and compressor are two distinct and separate units, and either one may be replaced without in any way interfering with the operation of the other.

The compressor proper, or air pump, is of exactly the same design and construction as that already described, and the instructions for inspection and maintenance already given (relating to the compressor and not to the motor) also apply to it. The capacity of this type of compressor is 25 cubic feet of free air per minute.

The motor is of the four-pole commutator type, with two consequent poles, and is designed for operation on voltages ranging from 500 to 600 volts direct current circuit, and on voltages ranging from 280 to 340 volts alternating current 25 cycle single phase circuit. The motor has two distinct field windings, one for alternating current and one for direct current. Laminated sheet steel pole pieces are used. The pole faces are provided

with a compensating winding, which consists of four separate coils, which are short-circuited upon themselves. The motor frame consists of three parts, the motor base, the magnet frame and the motor cover. The motor cover is bolted to both the magnet frame and motor base. The

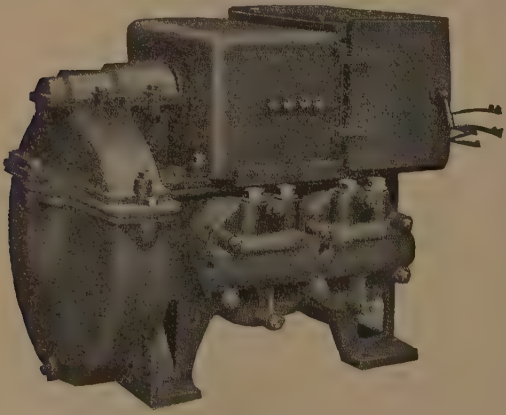


Fig. 86. A. C. D. C. Compressor. Type BB-2.

magnet frame is bolted to the motor base, and held in position by four cap screws, and is adjusted centrally with the armature, with reference to its vertical position, by means of shims, and laterally by means of adjusting screws.

The armature may be removed by taking off the motor cover, and removing the bearing cap, and cap screws which hold the magnet frame to the motor base, then lift the magnet frame and armature away from the base. The armature can then be taken out of the magnet frame

with ease. Fig. 87 shows the compressor partly dismantled and the armature removed from the magnet frame. The field coils are removed by first removing the armature, and then taking out the four cap screws that hold the pole piece on to the magnet frame. The pole piece can then be pushed in towards the center line of the shaft far enough to permit the field being removed. This can be done without disconnecting the compensat-

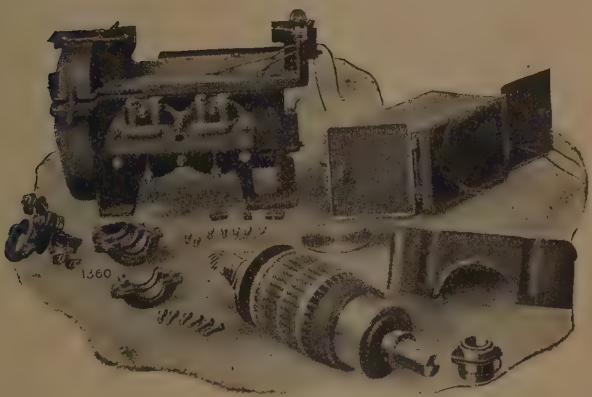


Fig. 87. A. C. D. C. Compressor Partly Dismantled.

ing winding, as the latter is flexible and can be bent as the coil is pushed inward or back into place. So long as the adjusting shims and set screws are not disturbed the magnet frame can be put back into its original position without any further adjustment.

The commutator is of high commercial quality hard-drawn lake copper, well proportioned and well insulated,

with a liberal wearing depth and is designed for severe service.

The brush gear is of the same distinctive construction as that used on the National direct current compressors, and differs from same mainly in the manner of fastening, and the number of brushes. The brush gear proper is securely fastened to a cast iron yoke made in two halves, which is secured in a groove running entirely around a projection of the armature bearing at the commutator end of the motor. Two sets of brush holders of two brushes each are used. The holders are fitted with an improved spring tension device, which is constant over a wide range of variation, and is also capable of an easy and correct adjustment.

The very liberal insulation of this brush gear gives it a maximum protection against insulation troubles, as may be seen by the fact that the external leakage surface of this insulation is 1¼ inches. The inspection of the armature, commutator and brushes is rendered an easy and quick process by means of the inspection doors at the sides of the motor casing.

METHOD OF STARTING COMPRESSOR.

The compressor is started by throwing it directly on the full voltage, either alternating or direct current. A relay is provided for automatically making the connections for running the motor either on alternating or direct current circuits, and is shown in Figs. 88 and 89. When the direct current circuit is closed the necessary connections for direct current operation are made by the solenoids of the relay attracting plungers to which are secured the contact pieces. When operating on the alter-

nating current circuit these solenoids are not in circuit, and the contact carrier drops by its own weight and makes the necessary connections for operating on alternating current. The relay is entirely enclosed and is, therefore, protected from the elements. A diagram of connections is supplied with each compressor and relay, and the leads are all tagged so that no wrong connections need be made.

Fig. 88. Relay Complete.

METHOD OF SUSPENSION.

The compressor is suspended in a cradle under the car body in the same manner as shown in Fig. 38. This method of suspension allows the entire pump to be exposed to the cooling effect of the air at all times, and

none of the parts of the suspension cradle obstruct the access to all parts of the compressor. The relay is mounted under the car body with the compressor.

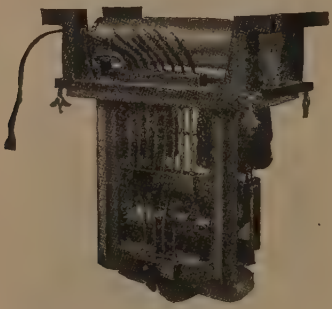


Fig. 89. Relay Without Cover.

The standard type "N" Oil Pneumatic Governor is furnished in connection with National A. C. D. C. Air Brake Equipments, and will operate equally as well on either direct or alternating current circuits.

THE CHRISTENSEN AIR BRAKE.

The Christensen air brake, while essentially a straight air brake system, may, like the National air brake, be made to operate automatically by the addition of the type J emergency valve. The Christensen air brake is manufactured by Allis-Chalmers Company, of Milwaukee,

Fig. 90.

Wis., and resembles in nearly every respect the National air brake. The Christensen motor compressors are classified under the following heading: Type AA1, AA4, B2, C3, and D4. Figures 90 and 91 show end and side views of type AA4 compressor, and the following table gives dimensions, capacities, and other data relating to the different types of compressors:

Table Giving Data Relating to Compressors.

Compressor Number	Size of Cylinder in Inches	Revs. per Minute	Capacity in Cubic Feet Free Air per Minute	H. P. at 90 Pounds Pressure	Amperes of Fuses at 550 Volts	Size of Piping in Ins.		Dimensions in Inches			Weight in Pounds	
						Suction	Discharge	Length	Width	Height	Net	Boxed
AA-1	5 x2½	193	11	2	6	¾	¾	21 1/16	18 11/16	16¾	440	601
AA-4	5 x4	174	16	2.6	6	¾	¾	22½	24½	21½	600	775
B-2	6½x3	172	20	4	10	¾	¾	28 1/16	22¼	20 3/16	800	980
C-3	7½x4	172	35	7	15	1	1	32¼	24 3/16	23	1016	1368
D-4	8½x4	182	50	9.5	20	1	1	35 9/16	25	24⅜	1307	1618

Fig. 91.

The diagram (Fig. 92) shows in colors the arrangement of the piping and other apparatus, and, by reference to the numbers shown on the diagram, and the following description, a clear idea of the layout of the equipment may be obtained:

1. Electric motor-driven air compressor.
2. Box.
3. Cage for supporting box and compressor under a car.
4. Insulating coupling.
5. Reservoir for storage of the compressed air.
6. Automatic electric governor.
7. Cover for governor.

8. Insulating coupling.
9. Non-arcing enclosed fuse to protect the compressor motor.
10. Brake cylinder with hollow piston rod and loose push rod so as to allow of the hand brake being easily applied through the same lever system.
11. Pressure gauge.
12. Engineer's valve for admitting air to, and releasing it from the brake cylinder.
13. Handle for engineer's valve.
14. Cut-out cock for trailer connection.
15. Hose and coupling for trailer.
16. Switch.
17. Whistle.
18. Independent valve for whistle.
19. Brake lever rigging.
20, 21. Pipe and fittings.

There are two cylinders for the compressor, each of which is fitted with a single-acting piston of the most approved construction. A steel crank shaft, with cranks set at such an angle as to give the best balance to the moving parts, operates the connecting rods.

The top of the compressor is formed by the base of the motor, and the gear (of the Herringbone type), which is keyed on the crank shaft, is enclosed in a cast iron casing. The noise of the gear and pinion is almost entirely eliminated, for the reason that the teeth are cut to mesh with an accuracy which insures smooth and quiet running. The working parts of the compressor are enclosed. Thorough lubrication of all the moving parts is effected from an oil reservoir in the base, supplied through an oil-filling elbow. The latter also gauges the proper height of the

oil in the casing. The reservoir communicates with the gear case, carrying oil up to the pinion on the armature shaft.

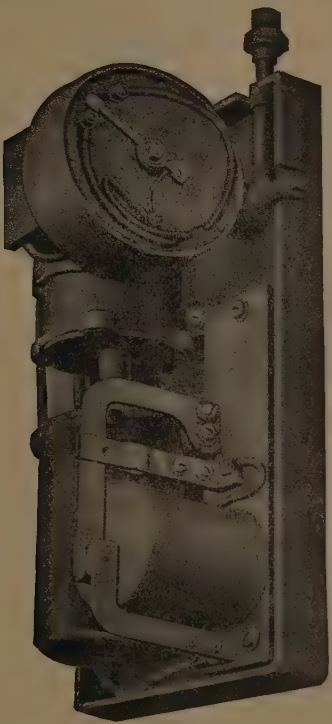


Fig. 93. Type "E" Governor, Christensen Air Brake.

In the cylinder heads the suction and discharge valves, of material and construction particularly adapted to the service required, work independently of each other. No

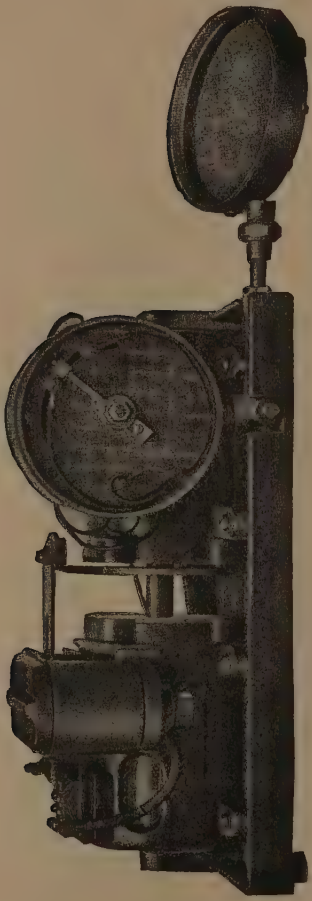


Fig. 94. Type E3 Governor (side view), Christensen Air Brake.

springs are used in connection with these valves, which are seated by gravity and can be changed about, at need, providing the seats have worn equally. The cylinder head, valves, pinion or gear may be removed, at any time, without disturbing the other parts.

MAIN RESERVOIR.

The air, as fast as compressed, passes into a suitable reservoir (of seamless, cold-drawn steel), where its volume is kept within proper limits by means of an automatic governor regulating the supply.

AUTOMATIC GOVERNOR.

The governor (Figs. 93, 94 and 95), which starts and stops the compressor, consists of an ordinary pressure gauge mechanism with a special hand. Its operation is very simple, as follows: When the hand comes in contact with a small stud at the position of minimum pressure, it allows the current to flow through a magnet coil. A plunger to which the contact pieces for the motor circuit are attached is operated by the magnet coil, thus closing the circuit and starting the motor. When the pressure reaches the desired maximum, the hand strikes another small stud, thereby causing the current to pass through a second magnet. As soon as this magnet is electrified the plunger is impelled in the opposite direction and opens the motor circuit.

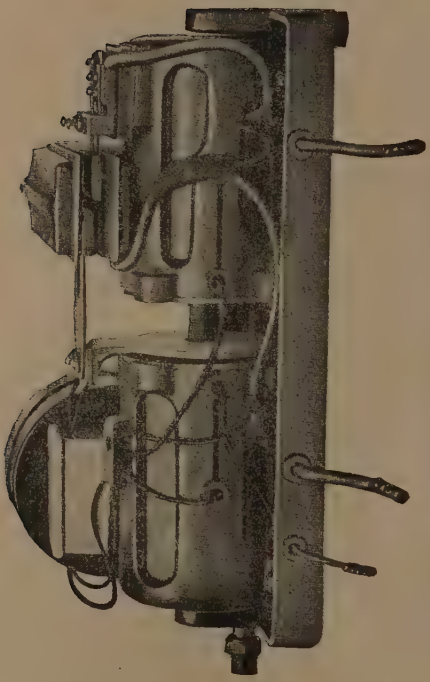


Fig. 95. Type E3 Governor (side view), Christensen Air Brake.

THE ENGINEER'S BRAKE VALVE.

The engineer's valve, by means of which compressed air is admitted from the main reservoir to the brake cylinder, and thence discharged into the atmosphere,

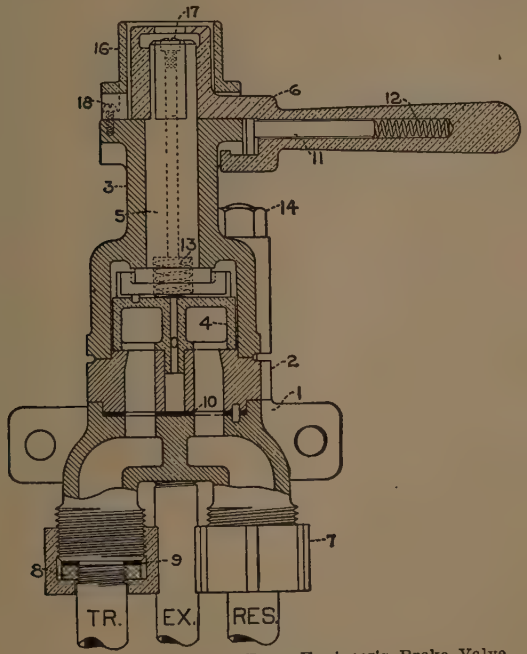


Fig. 96. Rotary Valve Type, Engineer's Brake Valve, Christensen Air Brake.

has been very carefully designed, so as to enable the motorman to manipulate it in a manner to secure the best possible results with the least consumption of air, also to make his stops without shock or jar.

This valve is furnished in either the rotary plug type, or as a slide valve. Figure 96 is a sectional view of the rotary valve, and the numbers in the following description correspond to those in the drawing:

STRAIGHT AIR ENGINEER'S VALVE.

Rotary Type, ½-inch, ¾-inch, 1-inch.

PARTS.

1. Base for rotary type.
2. Seat for rotary type.
3. Valve top for rotary type.
4. Valve for rotary type.
5. Valve stem for rotary type.
7. Union nut.
8. Ferrule.
9. Pipe gasket.
10. Seat gasket for rotary type.
11. Latch.
12. Latch spring.
13. Stem spring.
14. Tee bolt and nut.
15. Handle complete.
16. Guard.
17. Screw for oil hole.
18. Screw for guard, per dozen.
19. Rotary valve, complete, less handle.

Figure 97 is a sectional elevation of the slide valve type of engineer's brake valve, the parts being numbered and described as follows:

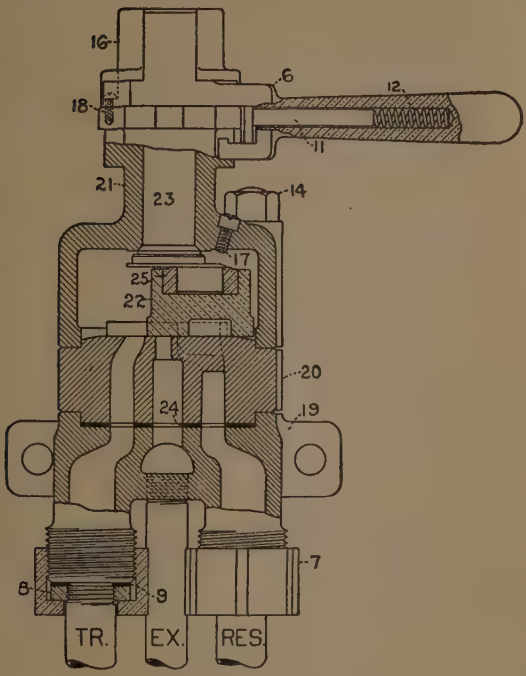


Fig. 97. Slide Valve Type, Engineer's Brake Valve, Christensen Air Brake.

SLIDE TYPE.

½-inch, ¾-inch, 1-inch.

PARTS.

7. Union nut.
8. Ferrule.
9. Pipe gasket.

11. Latch.
12. Latch spring.
13. Stem spring.
14. Tee bolt and nut.
15. Handle complete.
16. Guard.
17. Screw for oil hole.
18. Screw for guard.
19. Base for slide type.
20. Seat for slide type.
21. Valve top for slide type.
22. Valve for slide type.
23. Valve stem for slide type.
24. Seat gasket for slide type.
25. Auxiliary slide for slide type.
26. Slide valve, complete, less handle.

AIR GAUGE.

An air gauge is mounted near the engineer's valve in such a position as to be easily observed by the motorman.

BRAKE CYLINDERS.

When the brakes need to be operated, air from the main reservoir is admitted, through the engineer's valve, to the brake cylinder, which applies pressure to the shoes and thence to the wheels by means of suitable leverage mechanism.

The brake cylinder is provided with a loose piston rod so arranged that when the hand brakes, and not the air brakes, are used the loose piston rod only is moved.

The pipe in which it slides is fixed to the piston of the brake cylinder, which is held in release position by a spring.

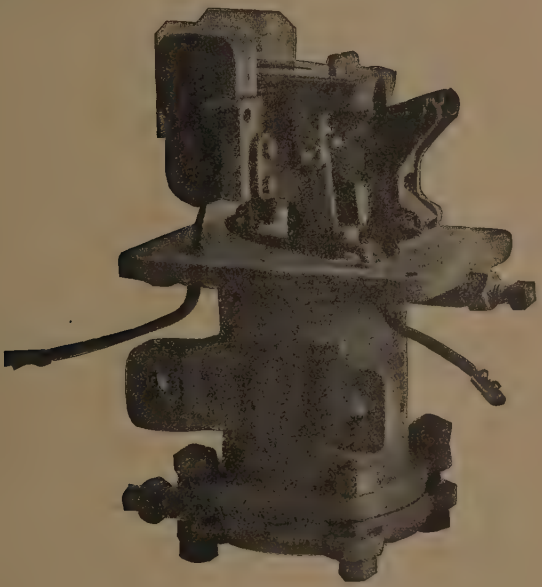


Fig. 98. Pneumatic Governor.

PIPING.

The necessary piping consists of two sections, viz.: the reservoir pipe, connecting the main reservoir with the engineer's valve, and the train pipe leading from that valve, which runs the entire length of the car or

train, hose couplings being used between cars. A stop cock at each end prevents the escape of air, when the opening is exposed.

Fig. 99. Pneumatic Governor—Case.

TYPE "OB" PNEUMATIC GOVERNOR.

It is, of course, a recognized fact that the reliable operation of an air brake equipment depends largely upon the governor, which, by automatically controlling the compressor, maintains the supply of air at any pressure required.

The type "OB" pneumatic governor furnished with the Christensen motor compressor, a view of which is given in figure 98 is shown in section in figure 100.

The main body, 1, contains a compression spring, 4, and piston, 3, upon which the air pressure acts. The

cap, 2, is machined to receive and secure the diaphragm, 5; it is bolted to the main body and tapped for pipe to connect to the main reservoir. The cap is so ar-

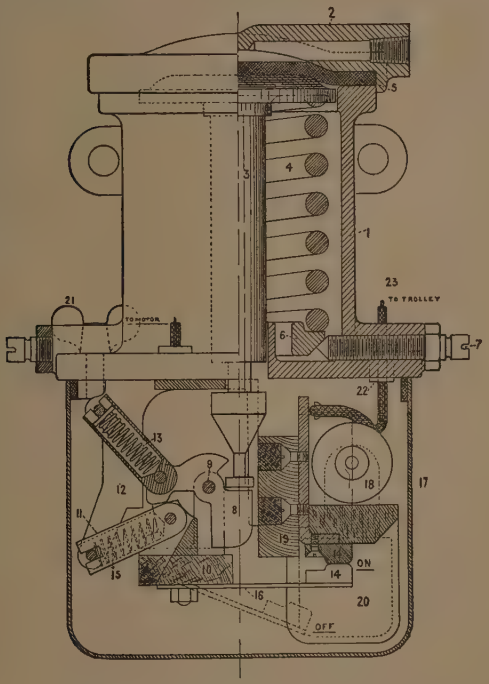


Fig. 100. Details of Type "OB" Governor.
(In reverse position from that shown by Fig. 98.)

ranged that pipe connections may be brought from any side to the governor, which is in direct communication with the main reservoir.

The diaphragm, 5, is made of pure rubber, specially prepared, insuring long life and flexibility, and avoiding the leaks that so commonly occur where piston packing rings, or leather gaskets are used. The piston and rod, 3, are made of steel. The compression spring, 4, which is inclosed within the main body, and well protected against tampering, acts upon the piston. The pressure is varied by adjustment of screws, 7, acting upon the spring washer, 6, whereby the spring may be compressed or relieved to suit requirements. The piston rod end is so shaped as to engage with a trip hammer, 8, and moves this over the center position past the pivot point, 9. When the pressure in the cap chamber above the diaphragm increases, the piston, 3, is forced downward, compressing the spring, 4.

The hammer, 8, being forced by the piston rod past the dead center, and aided by a spring, 13, in housing, 11, delivers a sharp blow to the yoke, 9, carrying the contact blades, 16, through which the circuit is opened and closed, which are made of bronze metal and well insulated against short circuit or ground. The copper tips, 14, are quickly separated and the arc completely extinguished by the powerful magnetic field. These contact tips are of liberal area, presenting large radiating surface. A separating shield prevents any possibility of the arc jumping across when the circuit is broken.

As the air pressure is reduced, the compressed spring, 4, at once commences to return to its former position; the piston rod, 3, again comes in contact with the trip hammer, 8, and reverses the movement of the latter; the yoke, 9, being carried over the center line of pivot point by the hammer, returns with a snap, aided by

springs 13 and 15, and closes the circuit. This quick return is important, as it prevents arcing and gives a wiping effect to the contact tips. The yoke is firmly held in either position by the tension spring, 15, and, in addition, is securely locked by the trip hammer, 8.

The quick brake mechanism is mounted upon a substantial brass frame, 12, and securely fastened to the main body, 1. The blowout coil, 16, and chute, 20, are mounted upon an insulating block, 19, which in turn, is attached to the frame, 12.

The small tension springs are protected by brass tubing, and are interchangeable, without affecting the accelerating action of the mechanism.

The electric terminals, 22, are brought out through the governor body and are well insulated by means of insulating bushings. They may be connected to either side of the line.

All pins and moving parts are made of hard brass, thus preventing corrosion. No lubrication to moving parts is necessary. The mechanism is protected against dust and water by a neat, light and strong cover, easily removable, which permits free access to the moving parts.

The variation of maximum and minimum pressure is accomplished by the adjustment of set screws, 7. The governor may be set between the pressure of sixty-five and ninety-five pounds, with an operating margin of ten pounds. For example, the governor can be adjusted to cut out at eighty-five pounds pressure, and it will automatically cut in and start the compressor when the pressure drops to seventy-five pounds.

Care should be exercised in connecting the governor to the air reservoir. The piping must be carried

directly from reservoir, and insulation coupling inserted in the line.

The governor will operate successfully in any position, and can be mounted below the cars or under a car seat. It occupies a space of 12 inches in height, 7 inches in length and 5½ inches in width.

Figure 101 shows the various parts of this governor.

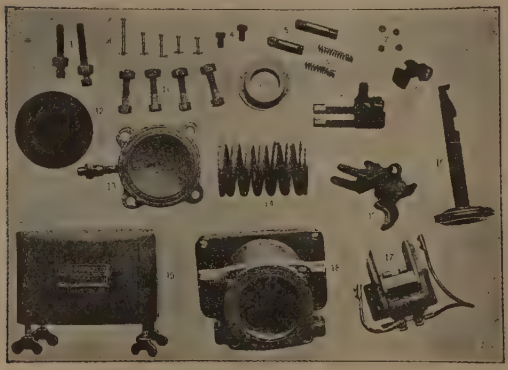


Fig. 101. Parts of Pneumatic Governor.

1—Adjusting Screw.
2—Carrier Shaft.
3—Pins.
4—Cap Screw.
5—Spring Housing.
6—Springs.
7—Nuts.
8—Knock-off.
9—Contact Carrier.
10—Spring Washer.
11—Bolts.
12—Rubber Diaphragm.
13—Diaphragm Cap.
14—Diaphragm Spring.
15—Carrier Frame.
16—Plunger.
17—Magnetic Blowout.
18—Body.
19—Cover.

TYPE "J" EMERGENCY VALVE.

The principal advantage of the straight air brake system lies in its simplicity and in the fact that the brakes may be applied and released gradually; but it has one serious defect, for, when two or more cars are

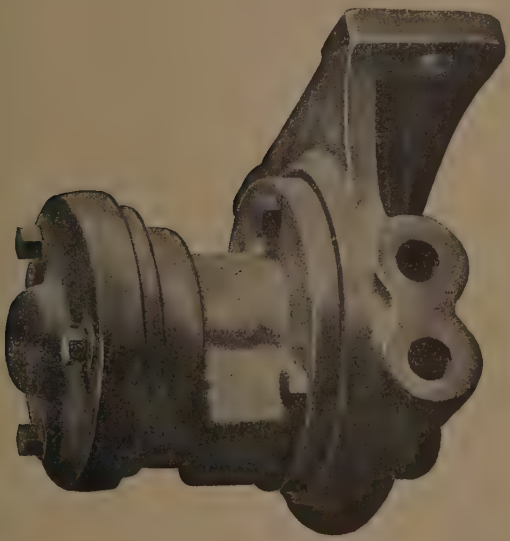


Fig. 102. Emergency Valve and Supporting Bracket.

run in a single train having this equipment, if the train should break apart, the brakes would not be applied automatically. Moreover, in the ordinary straight air system the control of the train is in the hands of the

motorman alone, whereas with the automatic system the brakes can be applied by the conductor in case of emergency from any one of the cars in the train.

The Christensen Air Brake system has, like the National Air Brake, an emergency valve attachment, by the use of which, in connection with the straight air system, practically all of the advantages of the automatic system may be realized. The working parts of the emergency valve (type J) are few in number, consisting merely of a slide valve operated by a piston and a release spring moving in the air chamber. The train pipe is required as a part of the equipment only in cases where the motor car pulls trailers on which there is no controlling apparatus. Where two or more motor cars, or the motor and the trailer car are provided with a controlling device, no additional hose connections are required, as in such cases it is only necessary to connect all reservoirs by means of an auxiliary hose in addition to the one provided for the straight air brake train pipe. The manner of applying the straight air brake, when equipped with the emergency valve, remains unchanged, since there is an unobstructed opening between the straight air train pipe and the brake cylinders when the emergency valve is in released position.

A passage between the main reservoir and the emergency line is provided to maintain, throughout the train, pressure in the latter equal to that in the main reservoir, while pressure is being raised in the main reservoir by the compressor. An additional orifice between the main reservoir and the emergency line, connecting the latter to the slide valve chamber, while being in direct communication with the auxiliary

reservoir, also keeps the auxiliary reservoir charged to the same pressure as the emergency line and main reservoir.

CONSTRUCTION OF THE EMERGENCY VALVE.

The Type J emergency valve, illustrated in detail in figures 103 and 104, consists of a cast iron body, 1, having a brass bushing with ports, 5, communicating

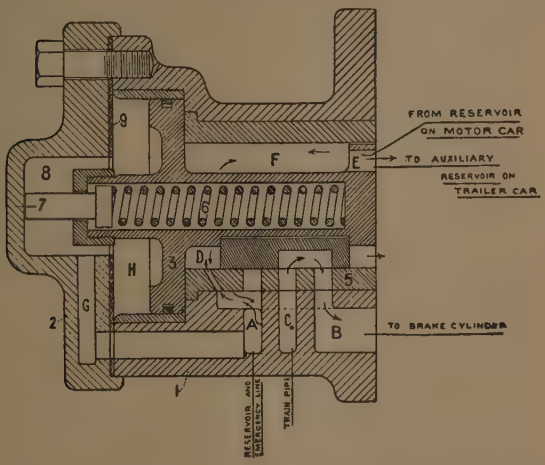


Fig. 103. Valve in Running Position.

with their respective pipe connections. The body is machined to receive the piston 3, and the slide valve, 4. A regulating spring, 6, is located inside of the piston chamber, resting against a compressing pin, 7, which in turn is secured by the cap, 8.

A suitable cap, 2, provided with a leather gasket, encloses the working parts. This cap is secured to the body by three bolts. All working parts are rendered easily accessible by removing the cap from the body.

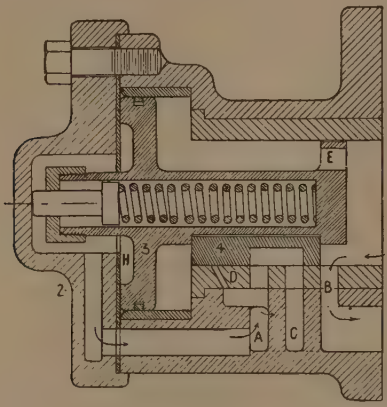


Fig. 104. Valve in Emergency Application.

APPLICATION OF EMERGENCY VALVE.

Fig. 103 shows the emergency valve in its ordinary position in a straight air equipment. Ports B and C are in direct communication with the brake cylinder and engineer's valve. Ports A, B, C and E are connected with their respective lines. On a motor car port E is connected to the main reservoir. The air from the main reservoir passes through port E into a circular chamber F, and through restricted opening D into A. In chamber A the air divides, passing through

channel G into chamber H behind the piston, 3. At the same time air travels through A to the emergency line and through a flexible connection to trailer cars, entering each respective valve at port A, filling chambers A and H, passing on through opening D into chamber F, and then through E to charge the auxiliary reservoir.

Fig. 104 shows the valve in emergency application. Upon a reduction of pressure in the emergency line, due either to the opening of the conductor's valve, or a parting of connections, piston 3 will be forced back against cap 2, carrying with it slide valve 4, uncovering port B and closing port D. Air will rush from the reservoir through port B into the brake cylinder, and bring the car to a full stop.

The release of pressure from the brake cylinder is brought about by balancing the pressures on both sides of the piston, 3. This is accomplished by charging the train with the main reservoir pressure, admitting air to the emergency valve through the port C, passing it on through the cavity in the slide valve, 4, into chamber A1 and restoring the pressure in chamber H. When the pressure has been balanced the piston, 3, and slide valve 4, aided by the spiral spring, 6, will return to normal position, uncovering port D, and permitting the auxiliary reservoir to be replenished, and equalized with the main reservoir.

Port B will register through the cavity in the slide valve, 4, with port C, and communicate directly with the engineer's valve release port, whereby the brake cylinder will be relieved of all pressure.

OPERATION OF THE EMERGENCY VALVE.

Should a conductor's valve be opened, or the train become disconnected, air is allowed to escape to the atmosphere from the emergency line. The escape of air causes a rapid reduction of pressure on that side of the piston towards the emergency line, and thus un-

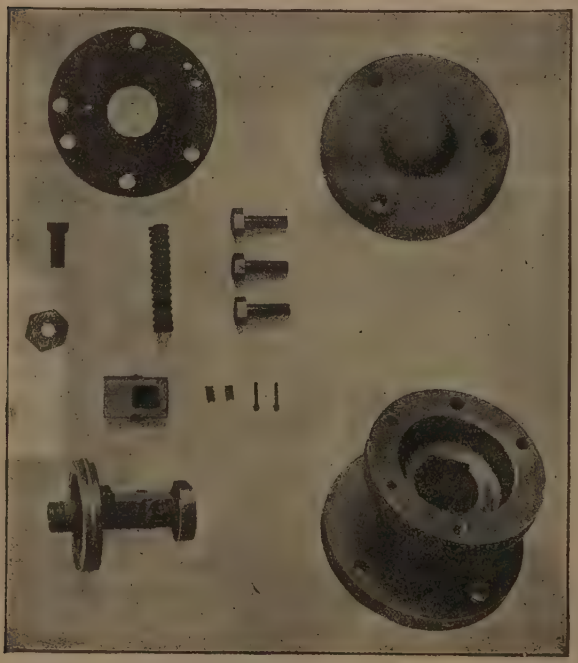


Fig. 105. Parts of Type J Emergency Valve.

balances the pressure, the result being that the greater pressure in the auxiliary reservoir forces the piston and slide valve to the extreme length of their travel. This causes the emergency valve to effect the following combinations:

1. The reservoir is disconnected from the emergency line, and is connected directly to the brake cylinder through a large orifice, which results in an instant equalization of the pressure in the brake cylinder and the auxiliary reservoir, thereby causing maximum brake pressure to be applied almost instantaneously, since the supply of air from the auxiliary reservoir has a much shorter distance to flow to reach the brake cylinder than is the case when it must travel from the main reservoir through the main air pipe, as in regular straight air brake systems.

2. The opening from the main reservoir to the emergency line is closed by the piston when it has traveled the full length of its stroke, which permits no escape of reservoir air through the open emergency line.

When cars are first coupled, the reservoir on the motor car should be filled up to full pressure, and the engineer's valve then thrown over to emergency position. In this position all auxiliary reservoirs will be rapidly charged. When all reservoirs are equalized the engineer's valve must be thrown to release position. After this operation, a full and direct opening has been established between the brake cylinder and the engineer's valve, and the emergency valve will remain inactive during straight air applications.

To release the brake cylinder and return the emergency valve to straight air position after an emergency application, the engineer's valve must be thrown to

emergency straight air application, so as to equalize the emergency line and main reservoir, and then returned to release position. This operation will return the emergency valve to normal running position.

In order to simplify piping, a special bracket is bolted to the car body to which the various pipes are connected. This also enables the emergency valve to be removed for cleaning and inspection without disturbing any of the connections. To avoid wrong connections the bracket is marked with raised letters.

The following apparatus constitutes a complete equipment for one motor and one trail car:

MOTOR CAR.

1 Motor Driven Air Compressor.
1 ¾" Insulating Hose for Compressor.
1 Suspension Box and Cage.
1 Automatic Governor.
1 ¼" Insulator.
1 Fuse and Base.
2 Switches.
2 Engineer Valves and 1 Handle.
1 Main Reservoir with Cradles and Hangers.
2 Air Pressure Gauges.
1 Brake Cylinder.
1 Emergency Valve.
4 Hose Couplings.
4 Dummy Couplings.
4 Stop Cocks.
Conductor's Valve if desired.

TRAILER.

1 Brake Cylinder.
1 Emergency Valve.
1 Auxiliary Reservoir.
4 Hose Couplings.
4 Dummy Couplings.
4 Stop Cocks.
Conductor's Valve if desired.

DRAWING.

(1) Section of Valve.
(2) Diagram of Equipment for 2 cars.

GENERAL ELECTRIC CO.'S AIR BRAKE

STRAIGHT AIR BRAKE EQUIPMENT

In the straight air brake system the brake cylinder is connected directly to the motorman's valve through the train pipe without intervening valves. The brakes are positively operated by the flow of air to and from the motorman's valve, being applied by an increase in the train pipe pressure and released by a corresponding reduction of this pressure. As a consequence, when the brakes are fully released there is no air in the train pipe.

The straight air brake system is specially adapted for single car operation, but may also be used if desired with a motor car and trail car, or two motor cars provided with multiple unit control. Hose couplings, cut-out, stop, and angle cocks are provided in such cases. When this system is used with trailers the brakes are not automatically applied if a hose coupling separates, or the train parts, and the safety obtained by its use is, therefore, not so great as that afforded by the emergency straight, or automatic air brake systems.

The general arrangement of this equipment is shown in Fig. 106.

The straight air brake equipment comprises the following parts:—

1: Motor driven air compressor.
2: Suspension cradle.
3: Governor.
4: Switch and fuse.

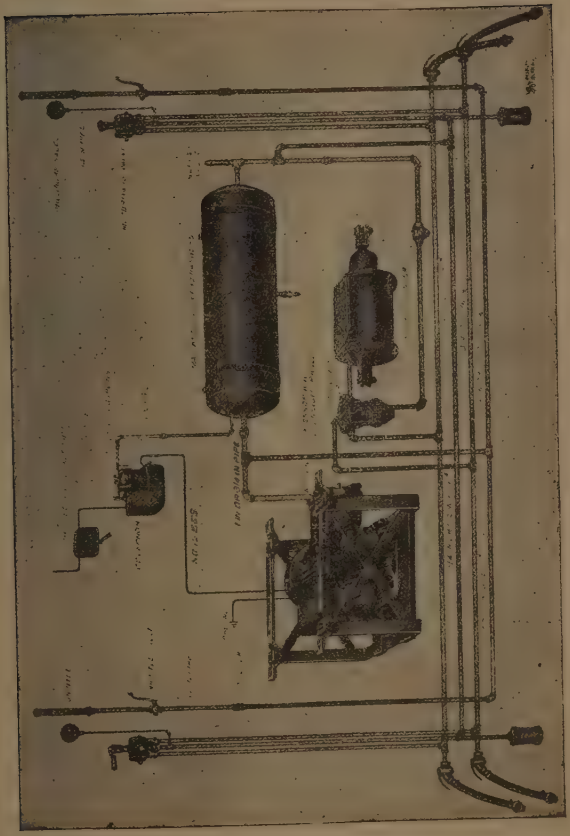


Fig. 106. General Arrangement for Motor Car Equipment.

5: Motorman's valves.
6: Brake cylinder.
7: Reservoir.
8: Safety valve.
9: Pressure gauges.
10: Cut-out, stop and angle cocks.
11: Hose couplings where trailers are used.
12: Whistle.
13: Exhaust muffler.

AIR COMPRESSOR

The air compressor is directly mounted on two oak planks supported in a cradle made of wrought iron bars. The cradle is suspended beneath the car from the floor beams.

The air compressor consists of two cylinders, with single-acting pistons connected to one crank shaft which is driven by an electric motor through herringbone gears. The cranks are 180 degrees apart so that one piston is compressing while the other is drawing air into the cylinder.

The motor has four poles, is series wound and entirely enclosed. The frame is of cast steel made in one piece with a removable head on one end, of sufficient size to permit the armature to be drawn out of the field. The pole pieces are bolted to the frame which forms part of the magnetic circuit. There are two brush-holders, each rigidly secured to, but insulated from, the motor frame.

The motor brush-holders can be adjusted to the wear of the commutator by unscrewing the clamping bolt at the end of the stud, which allows the brush-

holders to move towards, or away from the commutator. The holder should be set to within $\frac{1}{8}''$ of the commutator.

The motor commutator should be kept clean and inspected when the motor is running, to see that the brush tension is right and there is no flashing. If the commutator becomes rough, the armature should be taken out, and if necessary the commutator should be turned. After turning, it must be smoothed off with medium fine sandpaper to remove any ridges left by the turning tool.

Fig. 107. Air Compressor in Cradle.

To remove armature: Unbolt top and bottom halves of gear case from the frame, and remove gear case; then remove the gear and pinion, and motor frame head and brushes, leaving the armature free to be taken out.

In order to remove gear and pinion, gear and pinion pullers should be provided. The gear puller is a short piece of steel bar, with two holes drilled in it, whose distance apart is equal to that between the tapped holes in the gear hub. The pinion puller is a similar piece of

steel with its holes drilled to correspond with those tapped in the pinion hub.

To start the gear, first flatten down that portion of the lock-washer which is bent up, care being taken not to jam the gear teeth in so doing. Then take off the clamping nuts and lock-washers. When this has been done holes will be seen tapped in the gear hub. Place the gear puller against the end of the gear shaft, and screw two bolts into the tapped holes, through the holes in the puller until sufficient tension has been produced to start the gear from the tapered shaft. Perform similar operations on the pinion. The gear and pinion can then be withdrawn together.

Fig. 108. Motor Driven Air Compressor.

The gear or pinion may not always loosen when the bolts are screwed up tight, but in such cases it will be found that a slight tap with a hammer on the puller will generally accomplish the desired result.

Armatures must be taken out of the motor frame centrally to prevent rubbing and consequent injury to the insulating materials.

THE AIR COMPRESSOR comprises the following main parts: A crank case and two horizontal cylinders cast in one piece; a casting forming the two cylinder heads and containing the intake and discharge valves; a top crank case cover; a crank shaft; two pistons; two piston rods and the necessary crank shaft bearings. The gear end of the crank shaft is contained in a removable housing, so that the crank shaft can be readily drawn out. The intake and discharge valves are tubular, operating in a vertical position and are removable.

The connecting rods are provided with adjustable bearings for the crank pins. If a bearing is worn sufficiently to become loose, it can be tightened by removing one of the thin washers. Loose crank pin bearings sometimes cause pounding, but this is generally produced by damaged gears. If pounding occurs, examine the gears first for trouble, and do not tighten the bearings except when necessary. When taking up bearings, be careful not to get them too tight.

THE BEARINGS: The compressor is supplied with waste packed oil bearings, with the exception of the crank and wrist pin bearings.

To oil the crank shaft and wrist pin bearings, the crank case must be filled with oil through the filling elbow located on the side of the compressor frame. When the crank shaft rotates, the connecting rod heads strike the oil and splash it over the inside of the crank case, and such parts of the cylinders as are exposed, lubricating the crank shaft bearings, wrist pins and cylinders. In addition to the splash lubrication, small oil pumps are attached to the connecting rods, so as to lubricate these parts should the oil become low in the

crank case. The crank chamber must be replenished with oil once every month.

The four waste-packed bearings should be replenished with oil once every week. Only a small amount of oil should be put in at one time, two cubic inches being sufficient for each bearing. When oiling these bearings, the waste should be pushed down so as to make sure that it is touching the shaft. If the catch-basins are found to fill with oil, or to contain an appreciable amount of oil, too much oil has been put into the bearings, and the amount given to each can be safely reduced.

Compressors are sent from the factory with the bearing pockets packed with dry wool waste. Before starting the compressor, this waste should be removed and soaked in oil for twenty-four hours, to thoroughly saturate it. The oil can then be squeezed out and the waste put back into the bearings. The regular amount of oil can then be poured in on the top of the waste and the bearings are ready for use.

In putting the waste into the bearings it must be packed in tight, and must extend to the bottom of the pockets. The skein of the waste should be straightened out and folded before insertion so that the strings lie vertically parallel to one another when in place.

VALVES: Two valves are provided in the head of each cylinder,—an Intake Valve and a Discharge Valve. The intake valve allows air to enter the cylinder but prevents it passing out. The discharge valve permits air to pass out of the cylinder but prevents its return.

The intake valves (outside valves) are provided with a small vent hole in the bottom. The discharge valves (inside valves), are provided with a small vent hole in the side. These valves must not be interchanged.

Valve seats must be clean in order to have the compressor work to the best advantage. The valves, however, should not be touched, unless it is certain that they are not operating properly.

When a valve is removed, both the retaining pocket and valve should be washed with gasolene. The retaining pocket can be easily cleaned with a piece of cloth saturated with gasolene wound on the end of a stick. Waste or yarn must not be used for this purpose, as strings and lint are liable to be left in the pocket which may give trouble later. Before replacing valves all particles of dust should be carefully wiped off the valve seat.

The improper working of valves can easily be recognized from the sound made in operation. If the intake valve sticks, or does not properly seat, the escaping air can be plainly heard, and it will be noticed that the air compressor runs at a higher speed than normal. If the discharge valves stick or do not properly seat, the motor will be observed to be running slower than normal, and to be laboring under an overload. This increase of load is due to the air from the receiving tank filling the cylinders, and producing a constant high pressure on the pistons. It will also be noticed that the intake valves are silent, and are not opening, as the pressure inside the cylinders is never equal to, or less than atmospheric pressure.

Valve trouble is infrequent. The incoming air is drawn through a strainer box containing curled hair, and copper screens, to purify it before admission to the valves. The valves will generally give no trouble if the strainers are kept clean. They should be inspected from time to time to see if they are clean; in dusty or dirty weather this should be done every month. To clean

the strainers, take out the two bolts which hold the strainer box to the cylinder head; clean the copper screens and curled hair. The old hair can be cleaned by washing it in gasolene.

DIRECTION OF ROTATION: Air compressors are sent out connected so that the rotation of the armature will be in the proper direction. The motor armature must always rotate so that the top side of the commutator moves toward the observer when viewed through the inspection door.

UNDUE FRICTION in the air compressor is frequently the cause of the compressor motor fuse blowing. To locate the trouble examine the discharge valves to see if they stick, and all bearings to see if one is running hot.

PERCENTAGE OF TIME IN OPERATION: Under normal service conditions, the compressor should not operate more than a total of half the time the car is in service, unless there is an excessive leakage in the air brake piping.

The pipe connecting the compressor to the reservoir should be free from pockets where moisture might collect and cause trouble due to freezing *

SUSPENSION CRADLE: Illustrated by Fig. 107, is designed to allow the compressor to be removed without disturbing the bolts holding the cradle to the car body.

TO REMOVE AN AIR COMPRESSOR: If space allows, take out the holding down bolts, and then slide the compressor off the plank forming the base of the suspension cradle. If this cannot be done take out the four bolts holding the suspension hangers to the longitudinal bars which are permanently bolted, or lagged to the car frame. The

*This pipe should be 1 inch in diameter in the case of the CP-22 compressor and ¾ inch in diameter in the case of the CP-21 compressor.

suspension cradle can then be moved towards the center of the car until it clears the longitudinal bars, when it can be dropped down.

The suspension cradle should be located so that direction of the compressor armature is across the car, and the intake screens must be protected as much as possible from wheel wash.

GOVERNOR

The Governor may be placed in an upright, or inverted position, either under a seat, inside the car, or in some protected location underneath the car, but it must be insulated from grounded portions of the car framing. It should be placed as near as possible to the main reservoir, to which it must be directly connected. Do not connect the governor to any pipe from the reservoir to the compressor, or to the reservoir line. The pipe connection should be as short as possible, and should drain towards the reservoir to prevent accumulation, and freezing of moisture.

The working parts of the governor are clearly shown in Fig. 109, which should be referred to in the following description.

The function of the governor is to start or stop the compressor motor whenever the pressure falls below or rises above certain predetermined pressures. The difference between these pressures is usually 10 lbs. The governor diaphragm A is held in place by adjusting spring C against the varying pressure of the air. When this pressure exceeds a certain amount, the diaphragm is forced down carrying with it piston rod D which turns lever E around its fulcrum F. This brings the pivot H above the center line of the tension springs J,

which connect the intermediate lever G with the contact carrying lever K. The action of these springs then pulls the end of the intermediate lever down, carrying the center line of the springs past the pivot P. The action of these springs on the contact carrying lever K is then

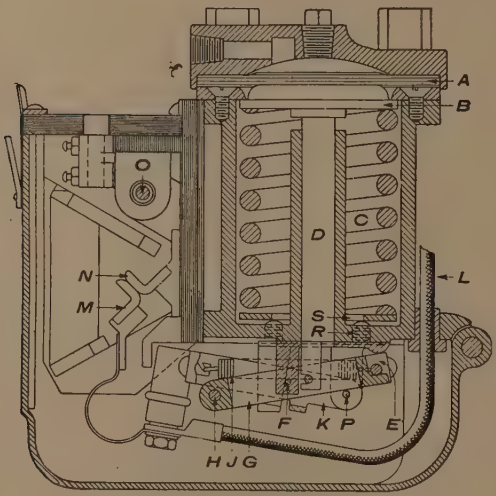


Fig. 109. Governor—Sectional View.

reversed, and the end of the lever is drawn downwards separating the contacts M and N with a quick snap, thus opening the motor circuit. This double system of levers is used to maintain a constant pressure between the contacts, until the tripping point is reached, thus preventing burning of the contacts.

As the pressure in the chamber above the diaphragm is reduced, piston rod D raises the back end of the lever E, engaging a projection of the latter with the intermediate lever G. The center line of the tension springs J is carried by this movement above the pivot of the contact carrying lever K. The contact finger is then pulled upwards by the action of the tension springs, and the circuit is quickly closed.

The magnetic blow-out on the upper part of the arc chute extinguishes the arc formed at the contacts, when opening the motor circuit. The arc chute is made of molded insulation, and can readily be renewed, if necessary.

All standard governors are adjusted for an opening pressure of 65 lbs. per square inch, and a closing pressure of 55 lbs. per square inch. The opening pressure may be increased up to 100 lbs. and the closing pressure to 90 lbs., by screwing in the adjusting screws for the spring C. To adjust the opening and closing pressure, first remove the locking screw and washer at the side of each of the two adjusting screws, then turn both adjusting springs an equal amount (to prevent binding the operating spring), until the proper adjustment is obtained.

To renew the rubber diaphragm, the cylinder head should be removed by unscrewing the four tap bolts holding it to the frame. When inserting a new diaphragm, see that the bolt holes in the diaphragm register with the corresponding holes in the cylinder head. A worn out diaphragm is easily detected by the governor opening at an increased pressure, and also by its greater operating range. To remove the operating spring from the governor, relieve its tension before removing

the retaining ring located next the rubber diaphragm. If the tension is not relieved, the retaining ring is likely to be thrown off with considerable force, due to the sudden release of the spring when the retaining ring screws have all been removed.

Governor contact tips should be inspected from time to time, and cleaned with sandpaper when necessary. To remove the contacts, unscrew the countersunk head screws holding the tips to the base. The spring carrying the contact tips must also be inspected to see that the proper wiping action takes place. The amount of this wiping should be $\frac{1}{8}''$.

As there is no air circulation through governors they are seldom affected by moisture freezing in them. In cold, damp climates, however, governor action sometimes becomes sluggish due to moisture freezing around the edges of the diaphragm. To prevent this, governors should be taken apart, and the chamber between the cylinder head and diaphragm thoroughly cleaned once a year, in order to remove all traces of moisture. The cleaning should be done in the fall of the year before winter sets in.

When installing the governor, see that the cable leading to the movable contact has not been pulled through too far, so as to interfere with the operation of the levers.

COMBINED SWITCH AND FUSE

The switch is provided for starting, or cutting out the compressor motor when desired, and the fuse is used for protection in case of short circuit or excessive overloads. The switch has a magnetic blow-out for ex-

tinguishing the arc, if the motor is taking current when the circuit is broken. The fuse is of the enclosed type, and of proper capacity. It can be readily removed by opening the cover and pulling out of the clips.

The switch and fuse should be placed in the positive side of the circuit, and the line lead must be connected to the contact in the upper left hand corner of the switch. The wire leading to the compressor should not be smaller than No. 12BS cable.

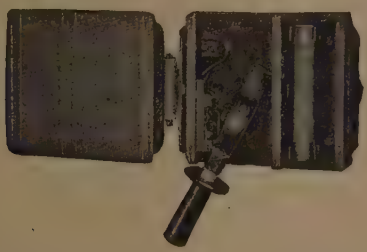


Fig. 110. Combined Switch and Fuse.

MOTORMAN'S BRAKE VALVE

This valve in its simplest form is a three-way valve. The three positions are respectively—Application, Lap and Release.

APPLICATION POSITION:—The valve admits air from the main reservoir to the brake cylinder.

LAP POSITION:—All connections are closed, and any air therefore, which has previously been admitted to the brake cylinder, is retained.

RELEASE POSITION:—Connection is made from the

brake cylinder to atmosphere, exhausting the air and releasing the brakes.

In order to obtain a gradual application of the brakes when slowing up, or for making a gradual stop, the Application Position is divided into two parts—Service Application Position, and Emergency Application Position.

SERVICE APPLICATION POSITION:—A small port admits air from the reservoir to the brake cylinder.

Fig. 111. Type S Form C Slide Type of Valve.

EMERGENCY APPLICATION POSITION:—A large port is opened admitting air from the reservoir to the brake cylinder, which applies the brakes almost instantaneously.

Two types of valves are manufactured—the rotary and slide valve.

The slide valve illustrated in Fig 111, consists of a

rectangular block, which is moved backwards and forwards by a cross head, which in turn is operated by a crank arm formed on the lower end of the valve stem. The slide type of valve is generally preferable to the rotary valve as the wear on the seat is more uniform, and, therefore, the valve remains tight for a longer period.

Fig. 112. Type S Form B Rotary Type of Valve.

The valve proper operates on a raised seat, and is surrounded by a removable yoke which fits closely at the edges of the seat, and acts as a guide to keep the valve in proper alignment. Regrinding is facilitated by this form of construction. The valve stem is provided with a square shouldered flange, forming a seat for a leather washer which makes an air tight joint with the valve bonnet.

The rotary valve illustrated by Fig. 112 is a disc valve rotated directly by the valve stem. The valve is centered by means of a guide pin in the valve body and is easily removed, which allows the valve to be readily reground when necessary.

Motorman's brake valves should be thoroughly lubricated at least once every month. To lubricate the valve, remove the valve bonnet, clean the valve and valve seat, and then apply a lubricant of grease and oil. Provision is made in the valve bonnet for oiling the valve stem. If a leak should develop between the stem and the bonnet, the leather washer should be removed and softened by immersing in oil for a short period.

VALVE INSTALLATION: Valves must be located at a convenient height above the car floor, so as not to interfere with the controller or brake handle. Before a car is placed in service, the valve should be taken apart and thoroughly cleaned and lubricated. This should be repeated after the car has been in service a week, to remove grit, and scale that has worked loose from the piping, etc., and to prevent, so far as possible, valve seats being cut. The valve handle should also be examined from time to time, to see that the pawl works freely, and indicates the notches properly.

BRAKE CYLINDER

The Brake Cylinder has a tubular piston rod, which surrounds a push rod to which the brake levers are connected. The push rod is arranged so as to move freely inside the tubular piston rod, when the brakes are applied by hand; so that hand and power application of the brakes are independent of one another. The pres-

sure heads of the cylinders have a forked extension to which one cylinder lever is attached.

Provision will be found in the pressure head for oiling, and a heavy cylinder oil or grease should be used.

It is important that brake cylinders should be kept clean, as otherwise the brakes will not release promptly when the air has been discharged. The cylinders should be taken apart and cleaned and oiled once a year. Only a small amount of oil is required for this purpose.

Fig. 113. Brake Cylinder.

RESERVOIRS

These are provided with connections to the following parts: The Compressor, the Reservoir Line leading to the motorman's valves, the Governor and the Reservoir Drain Cock. The connections at each end of the reservoir for the compressor and reservoir lines are tapped for a 1″ pipe and must be bushed down when a smaller pipe is used.

The governor connection which is located above the compressor connection in the end of the reservoir is tapped for a $\frac{3}{8}$″ pipe. This size of pipe should be used for strength and to obtain the necessary reservoir drain-

age. A $\frac{1}{2}$" drain cock fitted with a lever handle, is furnished with each reservoir. This handle points downwards when the cock is closed.

Reservoirs should be drained every day to remove any moisture which may collect.

SAFETY VALVES

These should be connected to the reservoir line in any convenient location to prevent too high a pressure accumulating in the reservoir, due to the failure of the governor. The valve is similar to the pop safety valve

Fig. 114. Safety Valve.

Fig. 115. Pressure Gauge.

used in steam practice. It can be readily adjusted by removing the cap on the upper part of the valve, and turning the adjusting screw.

All standard safety valves are adjusted to open at 100 lbs. pressure per square inch.

PRESSURE GAUGES.

When stop cocks are used, the pressure gauges should be connected to the main reservoir line at a point between the stop cock, and the motorman's valve. This arrangement should be followed so that when the cock is closed no pressure will show on the gauge. If, therefore, for any reason, air is cut off, the motorman's attention will be called to this fact, and that the brakes are inoperative.

CUT OUT, STOP, AND ANGLE COCKS

These are supplied when trail cars are used and for multiple unit operation.

The stop cocks are located near the hose couplings, and are for closing the train line when the trail cars are disconnected. Stop cocks should not be used for cutting out motorman's valves, except in case of multiple unit operation. Serious accidents have occurred, due to the brake valves having been cut out without the knowledge of the operator.

Cut out cocks are used with trail car equipments for disconnecting the brake cylinders in case of accident. The cut out cocks are similar to the stop cocks, except that the handle is at right angles to the slot in the plug, whereas in the stop cock it is parallel.

HOSE COUPLINGS

Hose Couplings with check valves are provided for use with trail car equipments. The check valve is arranged so as to close the train or reservoir line in case a train parts.

The hose couplings and rubber gaskets with which they are provided, should be examined from time to time to see that they are in good condition. If defective, they must be renewed.

WHISTLE

The whistles are of the deep tone organ type, and possess great carrying power.

Fig. 116. Whistle.

They are operated by an independent valve placed in the motorman's cab or vestibule. A ½″ stop cock should also be connected in the pipe leading to each whistle, in order to disconnect the whistle in case the whistle valve becomes inoperative.

EXHAUST MUFFLERS

These can be supplied if required. They consist of an iron box filled with curled hair held in place by metal screens so arranged as not to interfere with the free discharge of air when the brakes are released.

They should be connected in the exhaust pipe from the motorman's brake valve, and should preferably be located underneath the car. The hair in these mufflers should be changed about once a year.

GENERAL INSTRUCTIONS

In calculating the brake leverage for car brakes, the levers should be so arranged as to give a total shoe pressure on the car wheels equal to 100% of the weight of the car empty, but fully equipped. The brake cylinder pressure should be taken at 50 lbs. to the square inch.

Fig. 117. Exhaust Muffler.

The brake rigging should be arranged so that the brake cylinder piston will not have more than 5″ standing travel when the brakes are fully on. This allows for wear of the shoes and spring in the brake rigging. A 5″ standing travel is equivalent to a 6½″ running travel. The play in the journal boxes and bolsters is increased when the car is running, therefore the lost motion in the brake rigging is also increased, and the running travel necessary for the piston is greater than the standing travel.

Brake cylinders should be attached to the car body with iron plates or forgings. Lock washers should be

used on the cylinder bolts to prevent cylinders working loose. When installing the piping on cars, all fins should be removed from the pipes. Whenever bends are necessary, they should be made long and easy, and the pipes should be blown out by steam or air, and rapped sharply during this process to loosen scale from the interior of the pipes. All joints should be tested with soap suds under pressure to insure their being tight.

No sags, or pockets should be allowed in any of the piping, to prevent moisture collecting. All pipes should be fastened securely to the car body to prevent vibration and loosened joints.

The pipe from the compressor to the reservoir must drain towards the reservoir, and should be located so that the vibration of the compressor will not loosen the pipe connections. This connection should be made as long as possible to cool the air, before reaching the reservoir. The cooling helps the precipitation of the moisture which is held in suspension in the air. The water so deposited then drains into the reservoir, which acts as a water trap, and prevents it being carried further into the brake system. For this reason it is important that the reservoirs should be thoroughly drained every day, as previously pointed out under heading—Reservoirs.

EMERGENCY STRAIGHT AIR BRAKE EQUIPMENT

The Emergency Straight Air Brake System has been specially designed for cars intended for operating a part of the time singly, and part of the time in short trains of two or more cars. The trains may consist of one or

two motor cars and trailer, or of two or three motor cars equipped with multiple unit control.

With this system the brakes will be applied automatically, if a train should part, and they can be applied by the motorman, even if the train coupling line between the cars is injured, by moving the valve handle to the full emergency position. For service application the brakes are applied, and released in the same way as in the straight air brake system.

The general arrangement of the equipments for both motor and trail cars is shown on Figs. 106 and 118 respectively.

The Emergency Straight Air Brake Equipment comprises the following parts:—

MOTOR CAR EQUIPMENT.

Motor Driven Air Compressor.
Suspension Cradle.
Governor.
Switch and Fuse.
Motorman's Valves.
Emergency Valve.
Brake Cylinder.
Reservoir.
Safety Valve.
Pressure Gauge.
Hose Couplings with necessary Stop or Angle Cocks.
Whistle.
Exhaust Muffler.
Conductor's Valve, if desired.

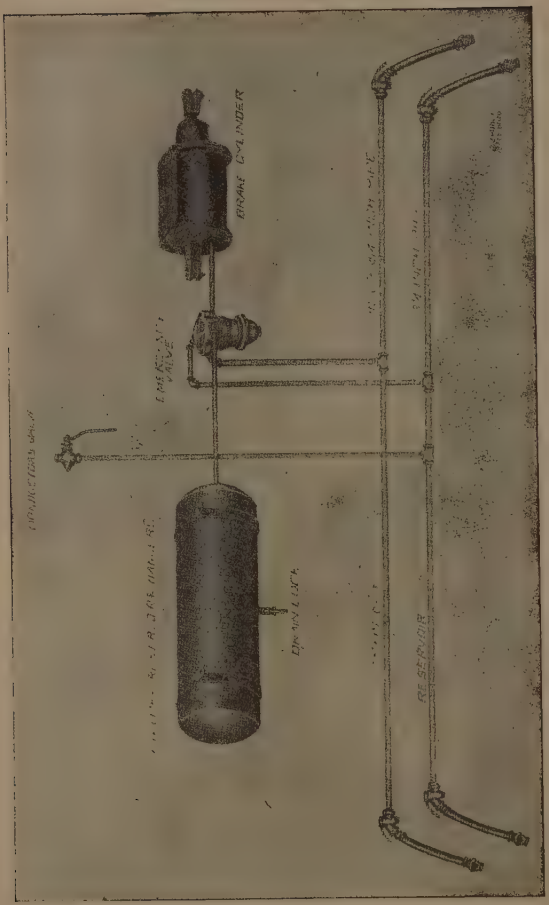


Fig. 118. General Arrangement for Trail Car Equipment.

TRAIL CAR EQUIPMENT

Emergency Valve.
Brake Cylinder.
Auxiliary Reservoir.
Hose couplings with necessary Stop or Angle Cocks.

The parts comprised in the motor car equipment are identical with those used in the Straight Air Brake System, with the exception of the Motorman's Valves and Emergency Valves. These two parts only will therefore be specially dealt with here, and for instructions on the rest of the equipment reference should be made to the instructions on "Straight Air Brake Equipments."

The parts that are common to motor car, and trail car equipments are the same, with the exception that the auxiliary reservoir for trail car equipments is ordinarily made smaller than that used for motor car equipments, in order to permit of a quicker release of the brakes after an emergency application has been made, and also to decrease the time necessary for charging the auxiliary reservoirs when a trail car is coupled to a motor car.

By consulting the general arrangement diagrams (Figs. 106 and 118) it will be seen that the main pipe connections are as follows:—

A pipe connection is made from the motor compressor to the reservoir, from which two other pipe connections are taken. One is taken directly to the motorman's valves at the ends of the car, thence to the train and reservoir lines running the whole length of the train. The other pipe connection is taken from the reservoir through the emergency valve, which has separate con-

nections to the brake cylinder, reservoir, and train line. An auxiliary connection from the motor compressor end of the reservoir is provided for the whistles at each end of the car.

The trail car pipe connections consist of train, and reservoir lines, which are coupled through the emergency valve to the auxiliary reservoir and brake cylinder. If a conductor's valve is used, a pipe is taken from the reservoir line for this connection.

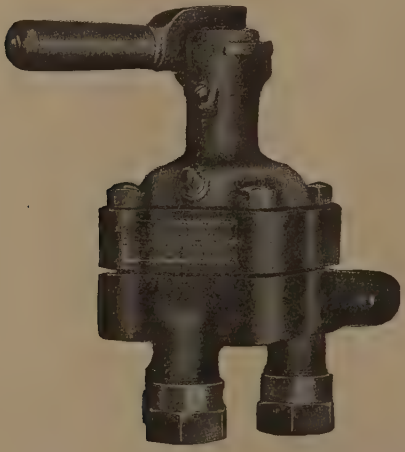


Fig. 119. Type S Form D Motorman's Valve.

MOTORMAN'S VALVE, TYPE "S," FORM "D."

This valve is of the rotary type and has four pipe connections. The first leads to the main reservoir. the second to the reservoir line, the third to the train line,

and the fourth, which is located in the center of the valve, leads directly to atmosphere. Beginning with the handle at the extreme left, the following are the positions and operations which occur in moving the valve through its successive steps.

This valve is illustrated in Figure 119 and a view of the parts named is shown in Figure 120.

1. Emergency Release Position:—The train line is connected to atmosphere, and the main reservoir is connected to the reservoir line.

The latter connection is made through a small port which charges the reservoir line to reservoir pressure, after an emergency application of the brakes has been made. The pressure above, and below the piston of the emergency valve is thus equalized, and the piston is forced back to the normal position by means of a spring located in the lower part of the valve.

The port connecting the main reservoir to the reservoir line is so proportioned that in case the train should part, and the valve handle is left in full release position, the air will not escape faster than it is supplied by the motor compressor, and the brakes will remain full on. Although this is the case, the valve handle should never be left in this position if a train parts. Under such conditions the handle must always be thrown to the emergency position. This application is more fully described below.

2. Service Release and Running Position:—The train line is connected to atmosphere, and the port connecting the main reservoir, to reservoir line is blanked.

3. Lap Position:—All ports are blanked.

Fig. 120. Parts of Motorman's Valve Type S Form D.

THIS IS THE ONLY POSITION IN WHICH THE HANDLE CAN BE REMOVED.

4. SERVICE APPLICATION POSITION:—The main reservoir is connected to the train line for applying the brakes.

This position is sub-divided into two parts:—

First—Service Position, in which the air is admitted to the train line through a small opening which permits a gradual application of the brakes, such as would be used for a slowdown or an ordinary service stop.

Second—Full Service Position, in which a large port is opened to train line, allowing the brakes to be applied rapidly. This position corresponds to the emergency position in the straight air brake motorman's valve.

5. EMERGENCY APPLICATION POSITION:—The reservoir line is connected to atmosphere.

In this position, the valve handle is thrown to the extreme right, which exhausts the air from the reservoir line, throwing the emergency valve to the emergency position, and admitting air directly from the respective reservoirs to the brake cylinders, thus applying the brakes on all cars in the train.

The action above described is identical to that which takes place in the automatic system, as the brakes are applied automatically if the reservoir line pressure is suddenly reduced. Such a reduction of pressure will take place when the motorman's valve is in position 5, or if the train parts, or the reservoir line hose l ursts.

In the Emergency Application Position of the motorman's valve, the connection from the main reservoir to the train line is cut off, which prevents air escaping from the main reservoir through the train line to atmosphere, in case the train should part or a hose bursts.

EMERGENCY VALVE, TYPE "E," FORM "F."

This valve is similar in operation to the triple valve used in the automatic system, except that the graduating valve is omitted. A sectional view of this valve is shown in Fig. 121. A view of the parts named is given in Fig. 122.

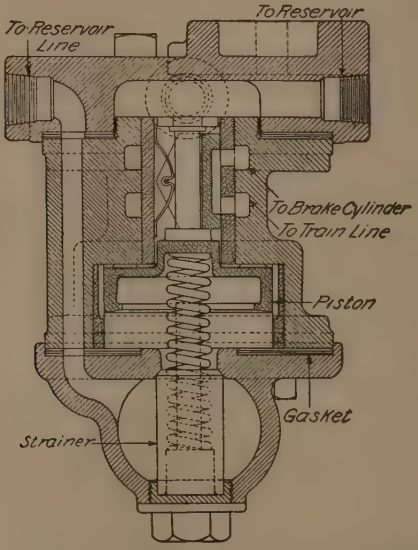


Fig. 121. Emergency Valve Type E Form F, Sectional View.

The pipes leading from the brake cylinder, reservoir, reservoir line and train line, are connected to this valve which is attached to a bracket located underneath the car. The valve is bolted to the bracket, and the parts

Fig. 122. Parts of Emergency Valve Type E Form F.

are so arranged that no pipe connections are made to the valve proper. It can, therefore, be removed for inspection or cleaning without disturbing any of the pipe connections.

The port marked "reservoir line" connects to the chamber in the lower part of the valve, and is connected to the reservoir line running throughout the train. The port marked "reservoir" is connected directly to the

Fig. 123. Emergency Valve Type E Form F.

main reservoir of the motor cars, or to the auxiliary reservoir of the trail cars. The pipe marked "brake cylinder," connects directly to the brake cylinder. The pipe marked "train line" connects to the train line running throughout the train.

OPERATION OF EMERGENCY VALVE.

SERVICE APPLICATION: When the valve is in the normal position as shown in the sectional view, communication is established between the train line and the brake cylinder, and the brakes are applied, or released by an increase or decrease of pressure in the train line.

During this operation, there is no movement of the slide valve, and the application and release of the brakes is made on all cars in the same manner as in the straight air brake system.

EMERGENCY APPLICATION: If the pressure of the air is suddenly reduced in the reservoir line, which connects with the chamber underneath the piston, the reservoir pressure in the valve chamber above forces the piston, and slide valve downwards. This movement closes the charging grooves around the piston, and the slide valve connects the reservoir directly to the brake cylinder when the piston has reached its lowest position, and at the same time closes the port to the train line. No air can then flow from the reservoir, to the reservoir line, nor from, or to the train line, but the full reservoir pressure is admitted into the brake cylinder.

If the motorman's valve is moved to the emergency position, which connects the reservoir line to atmosphere, or a reservoir line breaks, the brakes will be at once applied on all cars.

RELEASE: In order to release brakes after an emergency application has been made, the reservoir line must be re-charged to reservoir pressure. To do this, the handle of the motorman's valve is moved to the emergency release position. This allows air to flow from the main reservoir of the first car, through a small port

in the motorman's valve to the reservoir line, and also opens the train line to atmosphere. The pressures above and below the piston in the emergency valve are then equalized, and the spring moves the piston and slide valve to the normal position, connecting the train line and brake cylinder together. The air can then flow from the brake cylinder to the train line, thence through the motorman's valve to atmosphere.

PIPE CONNECTIONS.

Referring to Fig. 106, showing the piping arrangement adopted for emergency straight air brake motor car equipments, it will be seen that the whistles are connected between the compressor and reservoir. The position of this connection is important, and this location of the whistle is chosen to prevent violent fluctuations of the air pressure in the pipes near the emergency valve when the whistles are blown, which might throw this valve into the emergency position with a consequent application of the brakes.

A ¾″ pipe should be used for the train line, reservoir line, and for the connection from the reservoir to the emergency valve, and to the motorman's valves, in order to minimize the time required for applying the brakes. If an 8″ or 6″ brake cylinder is used, a ½″ pipe is sufficient for the train line, or for the pipes leading directly from the reservoir to the emergency valve, and to the motorman's valves. This size of pipe should never be used for the reservoir line, as quicker action of the emergency valve can be obtained by using the larger pipe.

If duplex gauges are used, the brake cylinder connection of the gauge should be piped to the train line side of the motorman's valve, and the reservoir connection connected to the pipe from the reservoir direct to the motorman's valve. The brake cylinder pressure would not be indicated by this arrangement if an emergency application of the brakes were made, and the train line therefore opened to atmosphere. This, however, is not very important, and the connections given above are recommended.

GENERAL INSTRUCTIONS.

Before putting the motorman's valve into service, it should be taken apart and all dirt removed. After the valve has been in service for about a week, it should be again taken apart and cleaned, in order to remove any collection of scale which may have been detached from the pipes.

This valve should be oiled with a lubricant composed of grease and oil once a month through the two ports provided for this purpose.

The Emergency Valve should be removed from its bracket, and cleaned after being a week in service. The valve should be drained, and the strainer cleaned at the same time, which can be readily done by unscrewing the nut at the bottom of the valve.

This valve should be thoroughly overhauled every six months to keep it in good condition, and should be oiled with a high grade engine oil.

The instructions given for "Straight Air Brake Equipments" should be followed in connection with brake leverage, piston travel, installation of pipes and apparatus under the car, location of the same, and joint testing.

The instructions already given should also be followed with reference to the air compressor, governor, combined switch and fuse, the installation of motorman's valve, brake cylinder, reservoirs, safety valve, pressure gauges, hose couplings, whistles and exhaust mufflers.

EFFICIENCY.

The Maintenance of Schedule Time, being one of great importance as a prominent factor in the expense of operation, the efficiency of the braking system is a subject calling for serious consideration. The best results are obtained from equipment only, when provided with a braking system of the highest efficiency, as the measure of value of a car brake is its ability to stop a car within the shortest possible distance when necessary, and any accessory means by which the braking system may be enabled to better perform its functions is an advantage of no little moment, and can be secured by the transfer of weight, during a brake application, in a one-way car, and this advantage may be obtained equally well on a hand brake car or one with power brakes, the latter, however, showing the best results from test made with both. The figures of one notable test recently made give the following results:

Total weight of car, empty, 26,000 lbs.

Level grade, dry rail.

Speed, 14 m.p.h.

Average distance to stop, hand brake, 79 feet.

Average distance to stop, air brake, 61 feet.

According to the strength and skill of the operator, it requires three to four seconds to secure the maximum pressure on the wheels with a hand brake car of

moderate weight; it takes longer to reach that maximum with a high leverage brake. All things equal, it would require the following distances to stop two cars running at a speed of 20 m.p.h.:

Hand brake car, 161 feet.

Air brake car, 124 feet.

As between stopping and starting, the former is the more important, as the safety of the service is more involved, and loss of brake efficiency is a factor of formidable degree in damage to person and property.

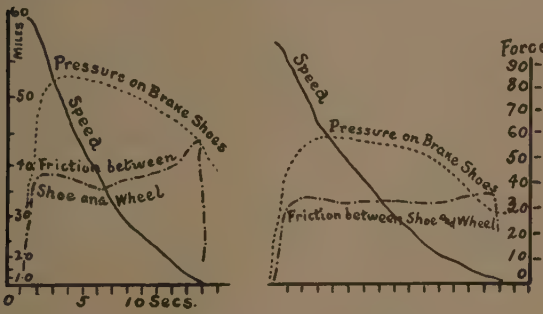


Fig. 124. The Westinghouse-Galton Friction Curves.

The possibility of skidding wheels depends solely on the speed, with high pressure brakes. The importance of automatic means for reducing the tension on the braking apparatus in proportion to the reduction of speed should not be lost sight of in the considerations of high braking efficiency, but as much improvement has not yet been successfully applied, the judgment of the operator of higher braking power must be relied upon, for the present at least. An important fact to be borne in mind by

the motorman is that with the same pressure, the retarding effect is less at high than at low speeds, as the friction of the brake shoes upon the wheels varies inversely with the speed, and calls for greater brake-shoe pressure upon the wheels at high speed. Time, distance, efficiency and the comfort of the passengers are the primary considerations, and which potentially may be claimed for a straight line stop.

The making of stops with the highest attainable degree of economy and efficiency will become a habit with the operator if, in the beginning, he will adopt as axiomatic the well demonstrated truth that the highest braking effect must be secured at the highest speed, and the pressure decreased in the ratio of speed reduction. The Westinghouse-Galton friction curves, Fig. 124, show the importance of this scientific application of brake pressure.

The amount of power required to skid the wheels limits the stopping power of a car, therefore the brake-shoe friction against the wheel should fall just short of a sufficiency to overcome the constant static rail friction. When the brakes are powerfully applied a sudden retardation is experienced and if the wheels then begin to skid, thereby losing the gradual decrease in their revolution, the momentum of the car will accelerate the speed again, as the friction on the rail will offer less resistance to the sliding wheels, than if the brake friction had gradually reduced the revolutions without locking the wheels entirely. If the car continues to slide along the rails, it will proceed a greater distance before stopping, than if the stop had been effected by the gradual decrease in revolution of wheels obtained by less than the full power suddenly applied to the brakes. By increasing the initial application

of less than full power and maintaining it at all times, a little less than sufficient to lock the wheels, the stop will be made in the shortest possible distance. The pro-

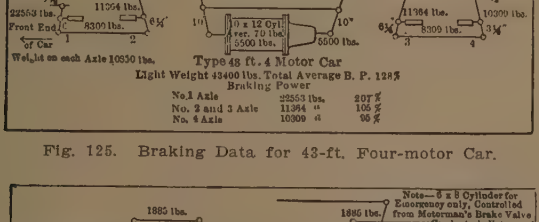


Fig. 125. Braking Data for 43-ft. Four-motor Car.

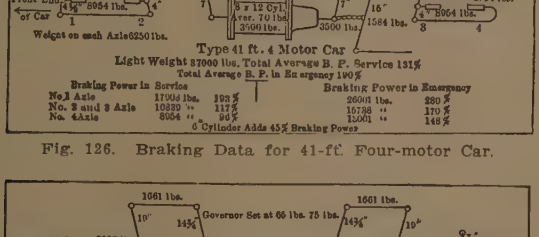


Fig. 126. Braking Data for 41-ft. Four-motor Car.

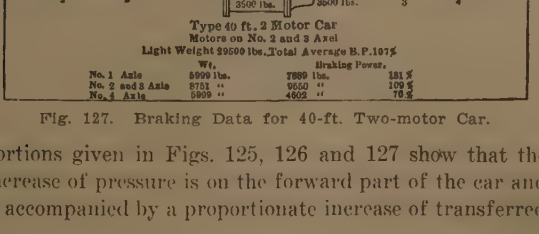


Fig. 127. Braking Data for 40-ft. Two-motor Car.

portions given in Figs. 125, 126 and 127 show that the increase of pressure is on the forward part of the car and is accompanied by a proportionate increase of transferred

weight due to the high center of gravity, although at first glance the total braking power may appear too high.

From the greater rail pressure of the front pair of wheels of the truck may be inferred a transfer of a part of the normal pressure from one pair of wheels to the other. As the transfer in weight from the rear to the front wheels of the truck will call for greater brake-shoe pressure on the front pair, the pressure on the rear pair must be reduced when applying the brake power in proportion to the difference in pressure caused by the shifting of the weight, otherwise the rear wheels are liable to become locked and skid.

Figs. 125, 126 and 127 show the leverage and braking power of three different types of cars, which was determined after a number of tests. One of these cars was a two-motor, and the other two were four-motor equipments of different weights, and the tests have reduced to a scientific truth the theory that the transfer of weight of a one-way car will increase the braking power, without additional operation expense. This increase in power varies with the height of center of gravity, truck centers and truck-wheel base.

The two-motor equipment with one motor on each truck (Fig. 127) shows that the total average braking power is 107 per cent, and the brake efficiency on the drivers is not reduced by reason of the idlers. The 41-foot four-motor car, Fig. 126, shows that in every maximum service application of the brake, a total average of 131 per cent is obtained, and a pressure of 193 per cent on No. 1 axle. When the 6-inch cylinder acts, a total of 190 per cent average is obtained, and the No. 1 axle rises to 280 per cent. Fig. 125 shows the 43-foot four-motor car to have a total average braking power of 128 per

cent and has the highest proportion on the No. 1 axle, which is 207 per cent in maximum service application, as it does not possess the 6-inch emergency cylinder feature. The truck wheel bases are:

Fig. 127, 4 feet 10 inches.
Fig. 126, 4 feet.
Fig. 125, 4 feet 9 inches.

The highest permissible operating proportion on the No. 1 axle has not been reached in any of these cases, but the strength of the truck frame permits carrying the pressure no higher at the top of dead lever.

This high braking power cannot be on a two-way or double-end car, as the limit of maximum power obtained up to the skidding point on the rear pair of wheels is about 95 per cent, which is the general practice for passenger cars for a 20 m.p.h. speed.

DEAD LEVER.

Many professionals otherwise well qualified in the maintenance and adjustment of existing brakes fail to grasp the function of the dead lever. As a rule shopmen think no more of lengthening or shortening this lever than they would of changing a brake rod. Nevertheless changing a dead lever changes the shoe pressure. Fig. 128 shows one-half of an inside hung brake rigging, the arrowheads show the directions in which a pull on rod AP will move the other lettered parts of rigging. Assuming a pull of 1,250 pounds on AP, shoe No. 1 will apply a force of (1,250×24/6), or 5,000 pounds. The bottom rod C D will be subjected to a thrust of (18× 1,250/6), or 3,750 pounds, which is the force applied to the lower end of the dead lever D X. Neglecting friction,

the force with which shoe No. 2 will be applied is then (3,750×24/18), or 5,000 pounds. Here the levers are proportioned alike, and the shoes subjected to equal pressure. Now suppose 6 inches to be cut from the top of the dead lever, all other dimensions remaining the same; the 3,750-pound force applied to its lower end will produce for No. 2 shoe a pressure of (3,750×18/12), or 5,625 pounds, which is 12.5 per cent more than on No. 1 shoe. This is an excessive allowance for even an excessive friction. Were the dead lever lengthened instead of shortened, a difference in the opposite direction would be secured. Tampering with the length of the dead lever is generally done either for convenience in anchoring its upper end, or because the upper end interferes with something else on the equipment.

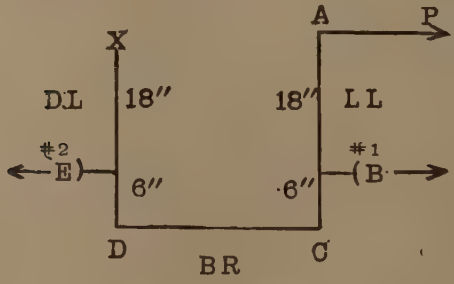


Fig. 128. DS Diagram.

ELECTRIC BRAKES.

The basic principle of the electric brake lies in its employment of the stored energy in a moving car to generate the current by means of which the car is stopped,

thus performing this function irrespective of the power station. The motors are connected to act as dynamos by the use of the B type controllers, which are used for electric brakes. When a car is to be brought to a standstill with an electric brake, the current passing through a resistance actuates a magnetic friction disc mounted on each axle, and also retards the action of the motors. To stop the car the controller is moved to the "off" position, which disconnects the car from the circuit. The handle is then moved to the special brake notches, which reverses the armature connections and connects the motors so as to effect a closed circuit through a resistance and the brake disc magnets.

The motors now generate the current, as the circuit being closed in this manner, they act as dynamos. This current causes the magnetic clutch on the axle to act and also retards the action of the motors, both of which occurrences combined brings the car to a standstill.

The Westinghouse Electric Brake is in the form of a track shoe which exerts both a downward pull—being held to the rail by its magnetism—and a horizontal drag. The shoe is magnetized by a winding energized by a current which the car motors produce. The vertical pull downward, acting through rods and levers designed for the purpose, sets the ordinary brake shoes against the wheels. This style of brake requires special braking notches in order to connect the motors so that they will generate the current, and conduct it to the track-shoe magnets and also a resistance to take up the excess of energy required to operate the brake.

Fig. 129 shows the construction of this brake.

The electro-magnet which divides the brake shoe into two parts is made fast to the two push rods by pins and

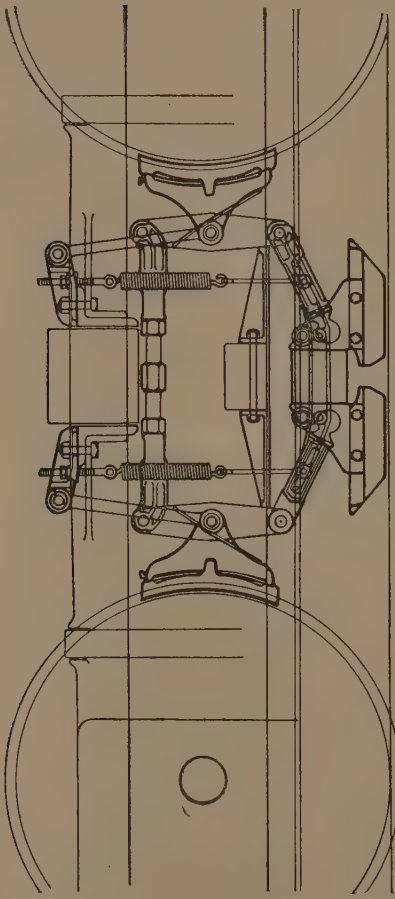


Fig. 129. Construction of Magnetic Brake.

is suspended by adjustable springs. The push rods are made fast to the lower ends of the brake levers by pins, and the brake levers are connected at their upper extremities by an adjustable rod, and are secured by a pivot to the brake-shoe holders and hanger links at an intermediate point. The hanger links are suspended from the truck frame. When the track shoe moves towards the right, the lower end of the brake lever on that side is also pushed in that direction, which causes the brake shoe to press against the wheel. The same motion causes the upper end of the same brake lever to move to the left, pushing the adjustable rod and the upper end of the brake lever at the left, in the same direction, which forces the brake shoe against the wheel. To facilitate this movement the push rods are made to work telescopically, as there are stops provided on either side which prevent the lower ends of the brake levers from following the direction in which the brake shoe moves on the track. The principle applied in the construction of the mechanism is very simple—just the evolution or development of the motion described by a needle pivoted vertically to a plane. When the lower end moves in one direction, the upper end moves in the opposite.

In this brake the motorman controls the attractive force of the rails upon the magnets up to a limit of 150 lbs. per square inch of brake shoe surface against rail surface. As the rail becomes the armature of the magnet, the strength of the latter is determined by the sectional area of the former. For very heavy cars a magnet of greater and sufficient strength is obtained by dividing the track shoe into three, instead of two parts, and winding it to form two electro magnets with a common pole, or a three pole magnet. This type of brake has two sets of resistances,

one on the exterior, and one on the interior of the car; the interior ones being employed to heat the car, which is effected by means of the braking, and starting currents and the amount of heat used in the car is regulated by combining the two sets of diverters in such manner as to supply the car with the heat it requires and permitting the surplus to escape.

The construction of this brake may provide for a variation in adjustment to increase the friction of the brake-shoe on the track rail. By changing the angular inclination of the push rods, and adjusting the levers to correspond, a portion of the weight of the car can be thrown upon the track shoes, and inversely the pressure of the brake shoes upon the wheels reduced. This adjustment, by which the adhesion of the track shoe to the rail is increased by weight of the car, is advantageous in wet weather, when the wheels have a tendency to slide, thus, to a certain extent, defeating the purpose of the brake shoe, as the force operating the wheel brake is reduced with the reduction of track magnet current, which declines with the speed when the car is being stopped. When the track magnet current is cut off, caused by the sliding, or cessation of wheel rotation, the pressure of the brake shoe upon the wheel relaxes, and the wheels resume their rotary motion.

The Price-Darling electric brake (Figs. 130 and 131) is operated by the trolley current which is cut off from the car motors by mechanism in the brake controller, designed for that purpose, and applied to the brake cylinders, the motors being converted into generators. The equipment for this brake consists principally of two brake controllers located on the platforms, an electro-magnetic brake cylinder, and an automatic controller and transfer switch under the car.

Fig. 130.

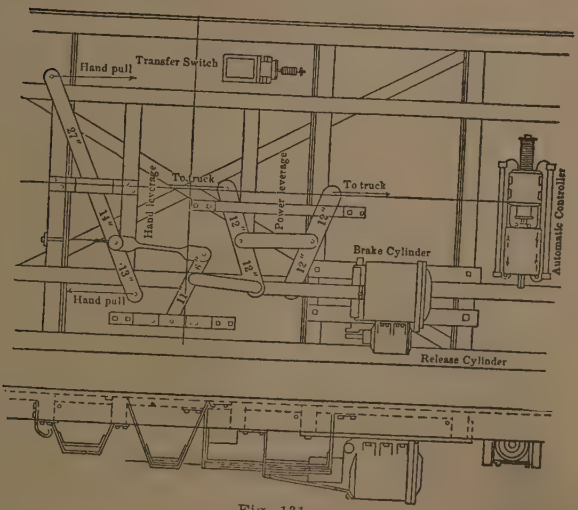


Fig. 131.

The brake cylinder is a solenoid with a movable core, which when energized in turn by the trolley current and the current generated by the motors actuates the system of brake levers causing the application of the brake shoes to wheels. In the operation of this brake the sliding of the wheels is provided against by the gradual application of the brakes as the speed of car is reduced, effected by the automatic controller which regulates the supply of current to the brake cylinder from the car motors. When sufficient current is generated by the motors, the trolley current is automatically cut off from the brake cylinder by the transfer switch.

The use of this brake enables the motorman to hold the car on a grade without the aid of the hand brake, as the system is provided with a locking device on the brake cylinder which holds the brakes in position without any power after they have been applied, and they are so held until released by the motorman.

EVOLUTION OF THE BRAKE SHOE.

A significant feature in the problem of successful train operation is the evolution of the brake shoe as a factor in deceleration, and one which has received a large share of the attention of experts in heavy electric railway service in recent years. The result of extensive study of brake shoes, to determine the cost, life, reliability, retarding effect and influence on the wear of the wheel tread, which has been given to the subject by some of the most prominent heavy electric railway systems, is considered of such educational value that it is briefly treated in this work, with a passing suggestion to those engaged in the operation of electric railways

that the subject is one calling for constant attention, and observation with a view to bring this important factor of car operation to its highest development of mechanical utility.

Previous to 1902 the shoes on some elevated systems were of the Corning type with square ends, as shown in Fig. 132. Subsequently the shoes were made with cast lugs, and of softer metal to provide against the ten-

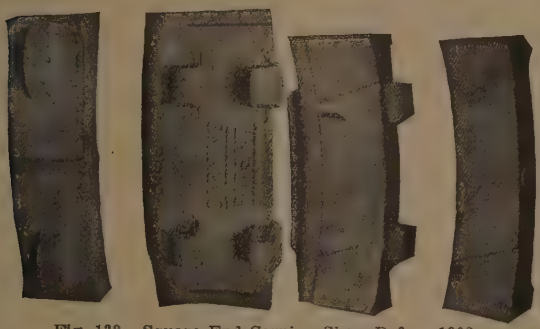


Fig. 132. Square End Corning Shoe, Before 1902.

dency to chip and crack, which is common occurrence with the use of hard metal. Later the cast lugs on the shoe were replaced by a stub of wrought steel, as shown in Figs. 133 and 134, to provide against brake failure through breakage of lugs.

By the addition of extended ends heavily chilled, and changing the shoe to the U type, it has increased the durability as well as frictional qualities, the chill remaining as in Figs. 133 and 134. Same change was also made in trailer shoes (Fig. 135) as regards the extended

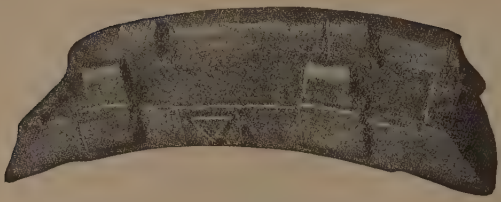


Fig. 133.

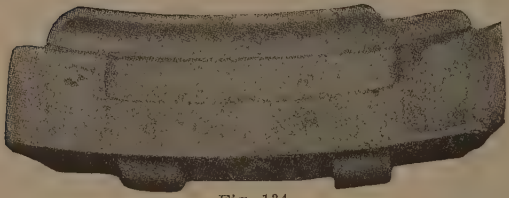
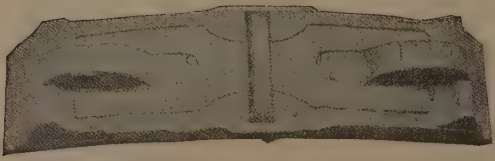


Fig. 134.



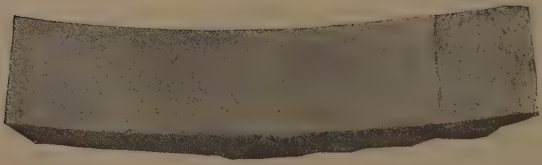


Fig. 135. Trailer, 1903 Type.

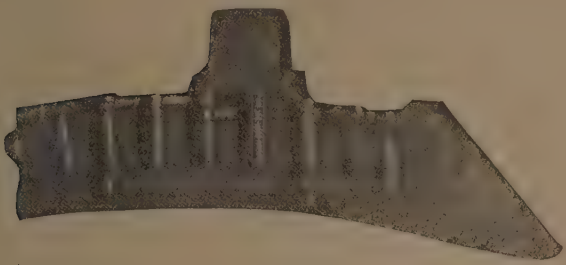


Fig. 136. Section of 1903 Shoe Showing Amount of Chill in the Ends.

Fig. 137. Worn Motor Shoe Shown New in Fig. 133.

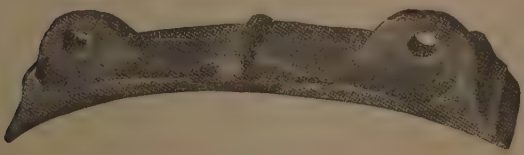


Fig. 138. Trailer Shoe, Scrap Weight 10½ lbs., 60 Per Cent Wear.

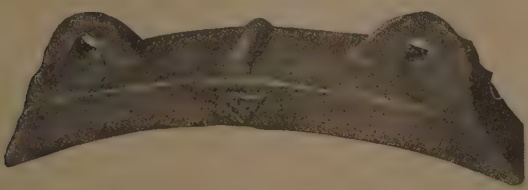


Fig. 139. Trailer Shoe, Weight 27 lbs. Net, 60 Per Cent Wear.

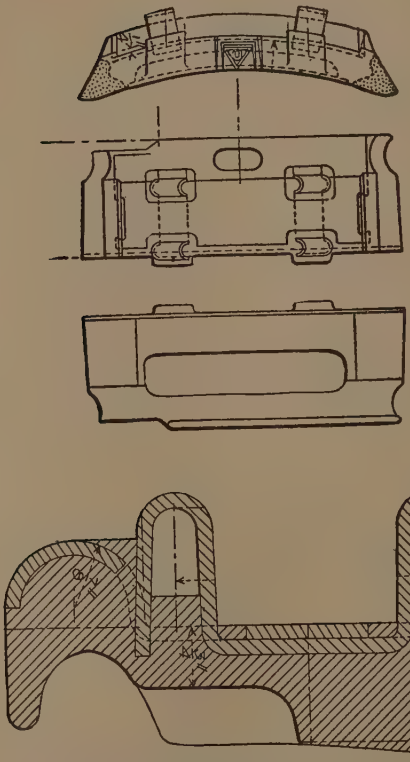


Fig. 140. Steel Back Brake Shoe for Motor Trucks.

ends, but the lugs of the trailer shoe, although very heavy, were not reinforced. Fig. 136 shows a section of the motor shoe, and indicates the amount of chill in the end of the shoe. Fig. 137 indicates, and gives a

good view of a scrap shoe of the standard type. The original weight of Fig. 133 is 35 lbs., and showed a weight when scrapped to average 17.9 lbs. (Fig. 137.) and leaves about 49 per cent for wear. Fig. 138 illustrates a trailer shoe when worn out. A new shoe of this type, Fig. 139, weighs 27 lbs., and the scrap is about 10 lbs., which allows about 60 per cent for wear. There are

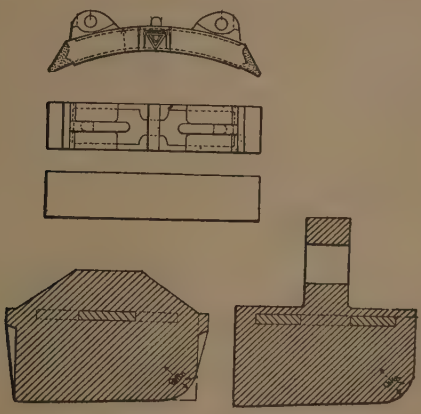


Fig. 141. Steel Back Brake Shoe for Trailer.

practically no failures with the above shoes, due either on account of the breakage of the shoes, or bad effects on the wheel tread. Many of these shoes are worn down to about $\frac{1}{4}''$ in thickness, and sometimes clear to the steel back. As the motor and trailer shoes are a close fit to the wheels at the start, the scrap weight is very low, and much less than could be accomplished with an unreinforced shoe, while the advantage of being reinforced against failure makes this shoe a satisfactory one

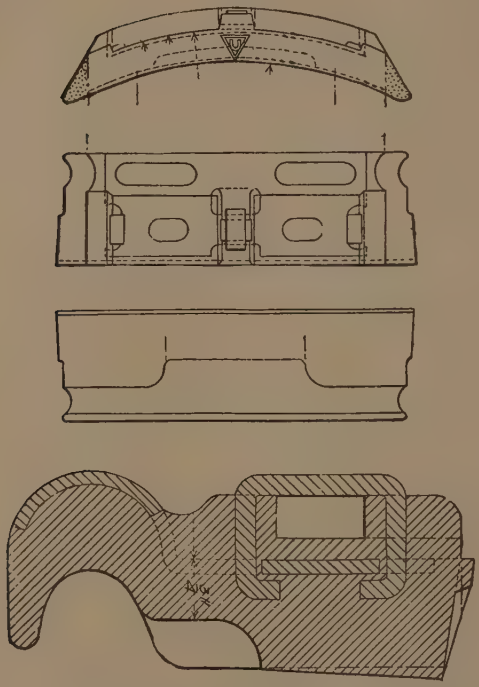


Fig. 142. Steel Back "U" Type Motor and Trailer Shoe in Use Previous to March, 1908.

for elevated equipment, as pieces of the shoe will not fall to the street.

Designs of some brake shoes in present use on heavy service roads will serve to show the advance in the type

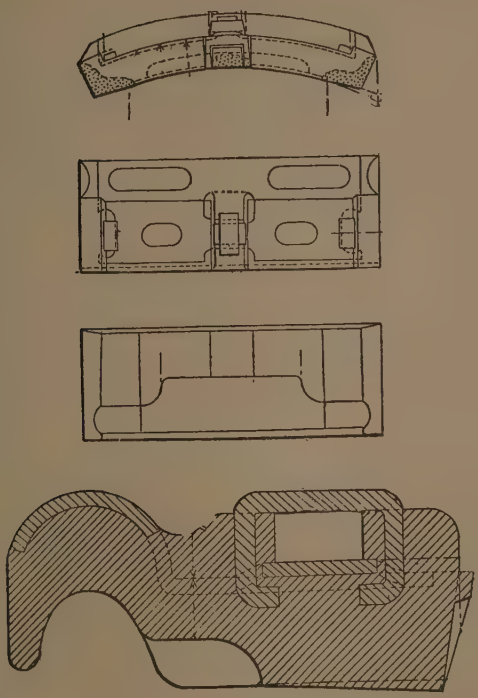


Fig. 143. Steel Back Type of Motor and Trailer Shoe with Center Chill and Toes Cut Off and in Present Use.

of brake shoes used in heavy traffic on some roads from the old Diamond "S" type used in early days to the present type of shoe introduced in 1908.

OPERATION OF BRAKES.

Whilst it is highly important that all motormen should possess an intelligent understanding of the machinery which they operate, it is not advisable that they should attempt such repairs as come strictly within the province of trained and experienced mechanics who are beyond the experimental stage; nor is it the policy of any well managed railroad corporation to permit unskilled employes to attempt the repairs of valuable machinery; still, there are emergencies continually confronting the motorman in which a knowledge of the construction, and working principles of the machinery in his charge will enable him to temporarily meet the difficulties which confront him at remote points when more skilful services are not attainable, and place him in position to run his car in for necessary repairs.

Whatever may be the brake system operated by the motorman, there are certain prominent features of operation which he should always keep prominently in view: The brakes should invariably be tested before leaving the car barn, and the motorman should be certain that the brakes are fully released before touching the controller. On a grade, to prevent receding of the car, the controller should be moved to start the car the moment the brakes are released. By the exercise of care in the handling of his brakes, the motorman can save much expense to the company, and relieve the public of unnecessary annoyance. Experience has demonstrated that the sliding of the wheels on the rails not only re-

duces the braking resistance and retarding force, but wears away the wheels, causing flat surfaces or "flat wheels," which entail the expense of removing, and turning down the wheels in the shops. Not to mention the intolerable noise, and consequent nuisance to the public which proceeds from a flat wheel before it can be taken into the shops for repairs, the incessant pounding must necessarily cause a certain amount of damage to track, especially at joints which are exposed most to lamination.

There has recently been developed a formula, expressing the kinetic energy of the blow delivered on the rail by a wheel with a flat spot. According to this formula the energy of the impact varies directly as follows: The weight of the wheel and its load; the square of velocity; the square length of the flat spot, and inversely the square of the diameter of the wheel. This formula disregards some minor considerations in the mechanics of the problems which probably do not affect materially the values obtained, but assumes a perfectly flat spot with sharp corners. With a 33 in. wheel, where the flat spot is 2½ in. long and carrying a load of 6,000 lbs. the kinetic energy of the blow delivered to the rail at a speed of 30 m. p h. is more than 1,000 ft. lbs. The assumption of speed and weight corresponds roughly to the extremes of heavy city service. The effect on both the rolling stock and track of the blows repeated many times per minute is very severe. While the damage to the rail is not likely to extend much below the surface, experience has shown that even surface indentations may cause rail breakings if the mills have not properly finished out the rails. To the crystallization of the metal produced by the constant hammering of flat wheels, the breakage of axle bearing lugs on motor castings are no doubt due,

Much of the impact is absorbed by the elasticity of the rails and ties in open-ballasted tracks, where the structure is yielding to some extent, but the full force of the blow is absorbed locally by the metal in the railhead in rigid tracks of paved streets.

The stopping of a car with the minimum of jar, jolt, wear and strain on machinery is, after all, a matter of good judgment in when, and where to apply, release, and again apply the brakes. A moderate application of the brakes at an estimated reasonable distance, when approaching the stopping point, which will tend gradually to slacken the speed, and a gradual increase of the brake shoe pressure when the stopping point has almost been reached, will effect an easy stop without undue strain or shock. On the other hand, it is not advisable to apply the brakes too far away when approaching the stopping, and make first, a reduction and then an increase in the speed, or sudden slacking and spurting forward. This is not only unscientific, and objectionable to the passengers, but it causes loss of time and unnecessary strain. An intelligent manipulation of the brake is the prime factor in the duration of the life of the brakeshoes and car wheels, and also insures an economical expenditure of stored energy.

THE FAILURE OF THE HAND BRAKE.

When the hand brake fails to work by reason of the parting of the brake chain or rod, or a breaking of the bolt by which the brake rod is secured to the brake lever, the situation may be considered a serious one whilst running on the line with a car load of passengers. This character of emergency calls for prompt action, and it

is well to proceed in such manner as not to cause alarm to the passengers. On a city run where traffic is heavy and the street crowded, the motorman should, immediately upon discovering the trouble, reverse the car and make a light application of the power, and signal the conductor to apply the rear brake. When the car has stopped it should remain at a standstill until the following car arrives on the ground, when arrangements should be made with the crew of that car to push the disabled car to the barns. It is possible, however, to run the car to the barns when disabled in the manner cited; but it is not advisable to do so when practicable to avoid it. With the conductor operating the rear brake, and the motorman in position to promptly use the reverser the car may be operated by a mutual understanding of signals arranged between the motorman and conductor; but the distance in which stops are to be made should be materially lengthened, and the power should be applied slowly when necessary to use the reverser.

The motorman should not in a case of this kind go beyond the third position on a controller car, and the first quarter would be the limit on a car equipped with the T. H. rheostat, as it is not necessary to apply more than just enough power to reverse the wheels in the opposite direction; any more than just sufficient power would in all probability blow the fuse, and in that case the only resource left would be to throw the controller handle clear around to the last parallel position.

When brake chains seem to have lengthened, so as to wind around the brake spindle abnormally, thereby preventing the car from being stopped within the required distance, or failing altogether to stop it, the trouble will

be found in all probability with the turn buckles, which may have been slacked off on the connecting rod of the brake. If the turn buckle has turned away from the check nuts, they should be turned back, and the car can then proceed on its run. A broken brake chain may also be readily remedied by blocking the car so that it will remain at rest, and then replacing the broken chain with the good one from the other end of the car. As every well equipped car should be provided with the necessary tools for such slight repairs as a motorman is permitted to make in an emergency, a monkey wrench will be found sufficient to make the change of brake chains and also to remedy any trouble arising from the breaking, or dropping out of brake rod bolts.

Recent tests on braking may have, with future additional data, a very significant bearing upon the final adoption of a standard and universal system, modified to meet the different conditions under which the many roads are operated.

Most companies at the present time have an electric brake for emergencies; but the exclusive use of this brake is rare. If the tests of electric, and air brakes which have recently been conducted upon a large scale, were compared, and the results obtained were platted, a curve would be obtained showing an advantage in favor of the electric brake over the air brake at high speed; but the reverse at low speed.

The consensus of expert opinion is, that in relation to wear of equipment, and maintenance of the various parts of the cars, the hand brake is the most expensive; the air brake coming next, and the least expensive is the electric brake. It has also been definitely determined that the use of the electric brake calls for an increase

in the capacity of the motors. In the adoption of a braking system, however, by any railway company, all of the conditions of operation should be taken into consideration, as the controlling conditions will necessarily justify the application of any one of the three systems best suited to such conditions, whether the system required be hand, electric or air.

It is advisable that the equipment of a car should include two complete systems, independent of each other, and the service brake should not require excessive muscular energy from the motorman.

An electric brake, or some mechanical brake, should be used when, on account of the weight of the cars, or the number of cars used, the hand brake is not adequate as a service brake. Where the capacity of motors for an electric brake cannot be employed, it is admissible to have some kind of air brake.

When trains or cars are run at a high speed, or when trains consist of more than two trail cars, the air brake is indispensable. It is claimed, however, in favor of the air brakes that they are ready at any moment, can be gradually applied, do not tire the motorman, permit the addition of any number of trail cars, and on the whole are more reliable.

MAINTENANCE OF HAND BRAKES.

The basis of almost all modern brake devices has been furnished by the first type of brake device used on ordinary road vehicles. They all proceed by a process of mechanical evolution from the primitive arrangement of two brake blocks and a beam operated by levers.

The most effective brake is that which applies the most friction to the wheel in the least space of time, up to a given percentage of the weight on the wheels. The ideal brake which is possible with power brakes, but beyond the potential performance of the hand brake, is that which would apply the maximum pressure on the initial application, gradually reducing the pressure in proportion to the decrease of speed, and consequent increase of the co-efficient of friction between the brake shoe and the wheel.

Winding of the brake chain on the staff is one of the most important of points in the transmission of braking power from the brake handle to the wheels. By using dynamometers in the truck pull rods, tests have shown that the breaking pressure at the wheels varies as much as 40 per cent with a given pressure applied to the brake handle on different applications on the same car. The manner in which the chain rolls on the brake staff indicated where the fault rested, and therefore care should be exercised to have a sufficient lead to the chain to permit it to roll on the staff without one turn running or binding upon the other, and for this reason a very close link chain should be made use of. A chain at the rear end of the car, catching on the snow scrapers, thus not permitting the application of brakes, is another matter which should be guarded against. For the protection of nuts working loose, or off from the eye bolts, or badly worn links, a frequent inspection is necessary. In order to prevent the chain from running against the platform, thus preventing the operation of brakes, great care should be exercised to see that the lead of the chain is prevented from winding above the eye bolt.

To prevent excessive fiber stress at all points due to vibration, suitable brake rods should be designed. Brake rods should also be designed for the greatest pull with ample provision for safety. Where the cross section is changed to any degree, rods should not be welded to the brake jaws at that point. The rod therefore should be upset enough to bring the weld from the point where the metal is reduced to the size of the rod. When offsets cannot be avoided they should be made as long as possible. Care should be exercised to see that the release springs have only sufficient tension to release shoes, and it should be remembered that every pound of tension on brake release springs means a pound of brake-shoe pressure lost. To get the best braking results, soft cast iron brake shoes should be used, although expensive on account of their short life, costly material and labor. Moreover they necessitate the adjustment of brakes more frequently than is convenient, as cars are not always available of such adjustment. It is therefore necessary to use medium hard shoes, or a combination of hard and soft metals, one having a soft cast iron body with chilled sections, or one with a soft cast iron body, and hard iron insert.

Case shoes with a different coefficient of friction can be used to advantage when it is not convenient to arrange brake leverage to give brake shoe pressure in proportion to the weight on the wheels. There is 25 per cent more brake pressure on the wheels of the brake lever end of the truck than there is on the wheels on the opposite end when equipped with a single motor on the brake lever end. This is of course only on certain short truck cars with 150 lbs. applied to the brake handle. It is necessary to have reinforced brake shoes, with

severe braking service; this reinforced brake permits the shoe to be worn thinner, and therefore means a less quantity of scrap.

By putting in link rubbers the cost of brake hose may be greatly reduced; but this must be done with care, for if the link rubbers are not snugly and properly fitted, the life of the rubber is very short, and therefore should receive careful consideration.

On some cars to prevent the links from breaking, a considerable amount of play is necessary, and an arrangement of two links, with a bolt in top and bottom, making a rectangular link with a joint in each corner, is very satisfactory.

In order to prevent flat wheels, and that the break pressure may be maintained on all the wheels just below the skidding point, a brake leverage should be arranged to distribute the pressure on all wheels in proportion to the weight thereon. In order to prevent serious binding on the sides of the fulcrum casting or guides at all points in the way of travel of the lever, care should be exercised to see that the movement of the lever is in the proper direction. This applies to single truck cars in particular. When both levers are brought in line, by shortening the vertical lever, and again locating the hole in the horizontal lever, a large difference is found in the braking power, and with little change of leverage ratio.

STORAGE AIR BRAKES.

This system is operated practically in the same way as other straight air brakes; but by compressed air which is delivered to storage tanks carried on the car from a large storage tank at central points, where the air is

compressed. The air capacity of the tanks on the cars is sufficient to last a car several trips over an ordinary city route, allowing between 250 to 500 stops. A reducing valve serves to lower the pressure in the main reservoir on the car to 50 pounds or less pressure, to the square inch, or enough to conform to the speed and weight of the car; the initial pressure being about 300 pounds. The air is supplied, therefore, from the main reservoirs of the cars to the auxiliary ones at this reduced pressure, of 50 pounds, and is from them allowed to pass into the brake cylinders by means of a valve controlled by the motorman. The brake is directly applied by the movement of two piston rods with which the brake cylinder is provided. These pistons are held by a spring with the end of one in close proximity to the end of the other, the intermediate space being occupied by the spring. When the brakes are to be set the motorman opens the valve which connects the reservoir with the space between the ends of pistons, thus forcing them apart against the spring tension and applying the brakes. When the valve is closed, and the air supply cut off from the space between the pistons, the action of the spring draws the pistons together again and the brakes are released.

WESTINGHOUSE STRAIGHT AIR BRAKE EQUIPMENTS.

Schedule S. M.

The straight-air brake may be installed with the motor-driven, or axle-driven compressors, or with storage reservoirs, its operation being independent of the source of air supply. The straight-air-brake equipment is only in favor for cars which operate singly. Straight-air-trailer equipment, Fig. 144, can be used for all cases where cars operate in trains of two or more cars.

There are three schedules of this equipment, designated, respectively, as "SM-1," "SM-2" and "SM-3." The arrangement of apparatus and its operation is the same in all three, but the details are different to suit the class of service.

The "SM-1" Schedule (Fig. 144) consists of the following:

1. A dust and water-proof, motor-driven, air compressor to supply the air for operating the brakes; it is suspended, so as to secure the best possible ventilation, in an open suspension cradle, which is so constructed that no vibrations of the machine are communicated to the car body, and any part of it is easily accessible for examination.

2. An electric pump governor designed to automatically stop and start the compressor at given maximum and minimum air pressures, the type and size of governor corresponding with the compressor; a "feed-valve" type, having independent maximum and mini-

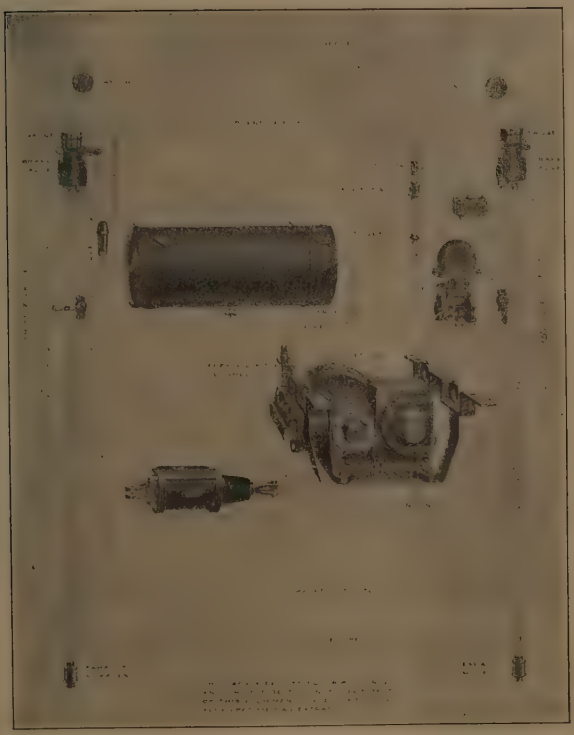


Fig. 144. Westinghouse Straight Air Brake Equipment, Schedule S M-1.

mum regulation, an air-operated cut-out switch, and pneumatic blow-out; or, a diaphragm and slide-valve type, with air-operated switch mechanism, mechanical quick-break cut-out device and magnetic blow-out; or an electro-pneumatic type with a solenoid quick-break cut-out device; also an insulating joint and cut-out cock for the governor piping.

3. A non-arcing enclosed fuse block placed in the wiring system that connects the trolley circuit to the governor and motor-compressor, to protect them.

Fig. 145. Brake Valve, Schedule SM-1.

4. An indicating snap switch for each cab, by which the current to the governor and motor compressor can be cut off at either end of the car.

5. A welded reservoir in which the compressed air is stored.

6. A brake cylinder of proper size to suit the car, the piston rod being so connected through the brake levers to the brake shoes that the hand brake can be applied without moving the piston.

7. For each end of the car a brake valve (Fig. 145)

of the slide-valve type, by means of which the brakes are applied and released; these valves being substantial in construction, simple to manipulate, economical in the use of air, thoroughly protected from interference, and provided with a duplex air gauge forming the top of the valve itself and arranged so as to be always under the motorman's eye.

8. A safety valve of special design to preclude the possibility of over-charging the main reservoir and piping system.

Fig. 146. Brake Valve, Schedule S M-2.

The Schedule "SM-2" differs from the one just described in the following particulars:

1. The electric-pump governor is of the electro-pneumatic solenoid type.

2. The fuse and block in the compressor circuit are of the same type, but not enclosed.

3. The brake valve (Fig. 146) is the same without the duplex air gauge, a single pointer gauge being substituted and mounted on the wall of the vestibule near the brake valve, and connected to the reservoir pipe under the brake valve, to show reservoir pressure only.

4. The safety valve is omitted.

The Schedule "SM-3" differs from "SM-2" as follows:

1. The brake valve is of the rotary type, very simple, having few parts, and provided with good oiling facilities.

2. The cut-out cocks are omitted from the supply under each brake valve.

The aims in equipping a car with air brakes are (1) safety, and (2) economy, in operation. To assure proper safety, the brake apparatus must be above all *reliable*, then simple, substantial, durable, easy to manipulate and understand. Experience shows that they can be relied upon to operate properly at any and all times. The parts that go to make up the equipments are all simple and easily understood. The appliances throughout have been designed to make meddling by unauthorized persons impossible. The brake valves cannot be turned when the handle is removed. The governors are reliable and efficient electric-pump governors.

Diagrammatic Illustration of the SME.

Straight Air Brake Equipment with Emergency Feature.

Fig. 147.

WESTINGHOUSE STRAIGHT AIR BRAKE

WITH EMERGENCY FEATURE.

Symbol "SME."

For Two-Car Train Operation.

It will be readily appreciated that the straight-air system, while simple and flexible in the extreme, and heretofore almost universally used for single cars, is not adapted for train service, since in the event of a rupture of the "cylinder pipe," due to the parting of the train, or any other cause, the use of the brake is immediately lost. In order to meet this condition—the seriousness of which is obvious—the straight-air brake, with the emergency feature, has been introduced. It is designed either for single-car operation or for trains not exceeding two cars. It will be observed in Fig. 147 that this apparatus is especially applicable for two combinations: First, a motor car and trailer, and, second, two motor cars. On many roads where transportation facilities are normally ample, but severely taxed during morning and evening rush hours and holidays, the use of a trailer has proven of very great advantage, increasing carrying capacity without a corresponding increase, either in the original investment or in the operating force necessary. As will be evident, with the ordinary form of straight-air brake there is a large element of danger in this practice, particularly where grades prevail, for which the "SME" equipment provides exactly what is re-

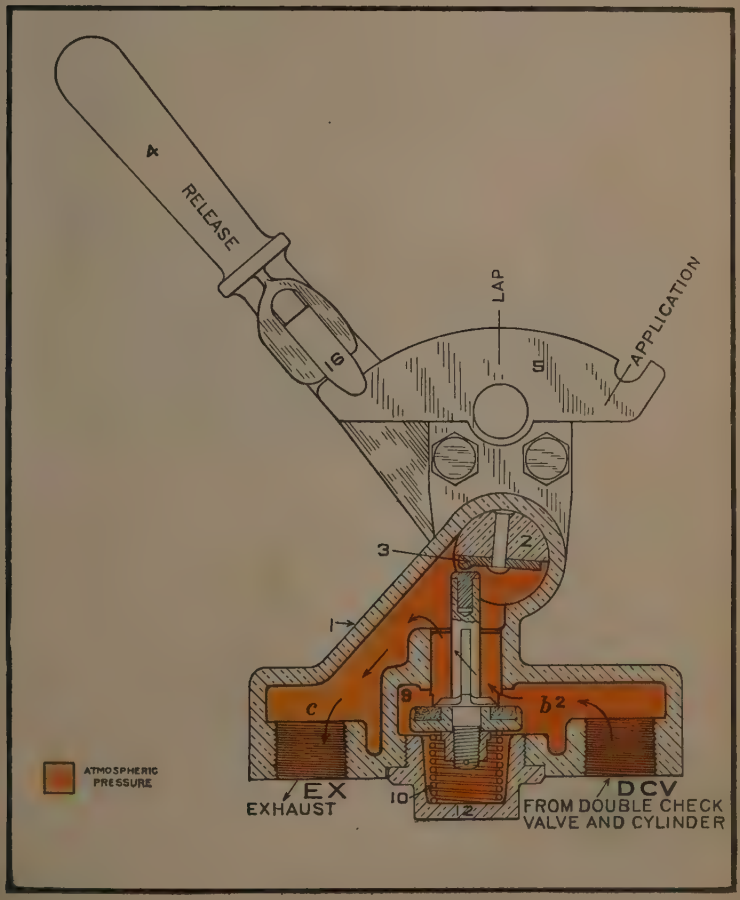
quired, inasmuch as this apparatus insures absolute control of both the motor car and trailer at all times, and, in consequence, a greatly increased factor of safety in operating under ordinary service conditions.

The next step in the development of the train service idea, and one to which progressive railway men have recently devoted considerable attention, is the combination of two motor cars. The advantages of this method of handling heavy traffic through congested districts are manifest, since train units of large capacity may be made up quickly and operated on short headway, thereby increasing the earning power of the system as a whole, while reducing the number of employees required. The straight-air brake with emergency feature is also recommended for this service, especially when the motor cars are operated separately a greater portion of the time and only at intervals in trains.

The advantages of the "SME" equipment are due to a novel arrangement of parts with particular reference to the brake valve and emergency valve, which embody a construction peculiar to this apparatus. By manipulating the brake valve, air pressure in normal service is admitted to and exhausted from the brake cylinder through the "cylinder pipe" as in ordinary straight-air operation. At the same time, by an ingenious arrangement of ports, pressure is constantly maintained in the "brake pipe." Should it be imperative to stop the train in the shortest possible distance to avoid accident, the brake valve handle is thrown to its emergency position, establishing communication instantly and automatically between the "brake pipe" and brake cylinder through the emergency valve, resulting in an emergency application. The brake valve (Fig. 148) is of

$\frac{3}{4}$ INCH STRAIGHT AIR BRAKE VALVE.

Release Position.



simple form, it has few parts, separate bracket for pipe connection, affords efficient lubrication, and wears uniformly between valve and valve seat.

The emergency valve (Fig. 149) controls communication from the "brake pipe" to the brake cylinder and operates only in emergency, at the will of the motorman, or automatically should the train happen to part. This device is bolted to a special cylinder head which carries all pipe connections, thus permitting easy removal for inspection, clearing and repair.

Fig. 148. Brake Valve, SME.

Fig. 149. Emergency Valve SME.

The brake cylinder (Fig. 150) is of a size, proportioned to the weight of the car in order to insure a satisfactory leverage ratio, has a piston rod designed to secure maximum efficiency of the hand brakes, which may be applied through the same leverage system, but without moving the brake-cylinder piston.

The air pressure is supplied by a dust and water-proof motor-driven air compressor (Fig. 151), with open cradle suspension to secure good ventilation and designed to

prevent the transmission of vibration to the car body, and also provides for easy inspection.

The automatic governor for controlling the operation of the compressor between predetermined maximum and minimum pressure limits, is of simple construction and reliable in operation under all service conditions. In the case of equipment for two motor cars, the governor is also designed to secure uniform pump labor on both cars.

Fig. 150. Brake Cylinder with Brake Valve, SME.

In addition the "SME" equipment includes a non-arcing enclosed fuse block and fuse, installed in the pump circuit to protect the motor against an excessive flow of current; a snap-switch for each cab, by which the current to the motor-compressor and governor may be cut off at either end of the car; a safety valve of improved design, to protect the overcharging of reservoirs and "brake pipe"; a muffler, which prevents the disagreeable noise due to brake-cylinder exhaust; hose couplings, providing flexible connections for "cylinder pipe" and "brake pipe" between the cars, and steel reservoirs, for storing the compressed air. The rec-

ommended reservoir capacity is divided into two units—first, by reason of greater convenience in installing, and second, to secure freedom from moisture in the brake system.

Fig. 151. Compressor, SME.

It will be apparent that this apparatus combines *safety and reliability*, which are the important and essential features of an automatic brake, with advantages heretofore peculiar to the straight-air system, chief of which is the ability to graduate the *brake at will* either in application, or release.

THE ELECTRIC LOCOMOTIVE.

RATING AND CAPACITY.

The rating of a steam locomotive is based on its maximum tractive effort, and its capacity depends upon the maximum speed at which this tractive effort may be developed. The maximum rate of doing work, for which it is possible to design a steam locomotive is therefore governed by practical limitations as to the steaming capacity of the boiler and the dimensions of the fire-box. On the other hand the electric locomotive does not generate its own power, but acts merely as a transmitting medium, through which electric power delivered by the central power station to the locomotive is converted into mechanical power at the driving axles. Each driving axle of an electric locomotive being equipped with a motor, the size and horse power of which is limited only by the speed at which it operates, by the gauge of the track, and by the diameter of the driving wheels, it becomes only necessary to provide a sufficient number of driving axles in order to design an electric locomotive capable of delivering the maximum tractive effort that the draw bars of a train will sustain, at any speed permitted by considerations of safety in operation, and a reasonable cost of track maintenance.

Herein lies the chief advantage of the electric locomotive, the increase in speed of the heavy freight trains making it possible to double and in many cases triple the tonnage capacity, and consequently the earning power per mile of track. For example, the most powerful

Fig. 152. New York Central Electric Locomotive.

steam locomotive in existence, the six-axle, twelve-wheel Mallet Articulated Compound, built for the Baltimore & Ohio Railway by the American Locomotive Company, will develop its maximum tractive effort of 71,500 pounds working compound, at a speed of less than 10 m. p. h., whereas an eight-axle electric locomotive having the same weight on drivers and composed of two four-axle sections coupled together (wheel classification 0880) could be made to develop an equal tractive effort at a speed of 30 miles per hour. It will be seen that such an electric locomotive could handle three times the daily tonnage of the Mallet Compound referred to above, increasing the traffic capacity of the road in the same proportion.

In converting electrical into mechanical power, part of the electrical power is lost in the windings, and in the magnetic circuit of the motors, taking the form of heat and causing a rise in temperature proportional to the power loss and to the radiating capacity of the motor. The losses, and consequently the temperature rise increase with the power developed by a given motor, and the maximum load cannot therefore be safely carried beyond the point where permanent injury to the windings will result from excessive temperature. Long experience with the various insulating materials known to the art has shown that the best of these cannot be repeatedly subjected to a temperature rise greatly exceeding 75 degrees C. above the air without deterioration. There has therefore been adopted for railway motors a standard rating, defined as the horse power delivered at the axle continuously for a period of one hour, with a rise in temperature not exceeding 75 degrees C.

The rating of the electric locomotive, like the steam locomotive, is based on the maximum tractive effort the

locomotive will exert for short periods of time, fixed by mechanical considerations, such as weight on drivers, and by electrical conditions, such as overload capacity of the motors. The capacity of the electric locomotive on the other hand, is determined by the heating of the motors in continuous operation, this heating being dependent upon the operating conditions, such as length of run, grade, curves, weight of train, schedule speed, number and duration of stops and lay overs.

Fig. 153. New York Central Locomotive with Train.

In order to provide a margin to cover changes in assumed operating conditions, and possibility of occasional increase in duty, the estimated temperature rise in service operation should not as a general rule be greater than 60 to 65 degrees C., although occasions may infrequently arise where a higher value may be safely taken.

FORCED VENTILATION.

In the smaller sizes of motors, where the radiating surface is large in proportion to the weight, it is possible to carry off excessive heat by natural ventilation. This method applies also to many of the larger sizes of locomotives in cases where the grades are light, and where the average power developed during the run is not greatly in excess of one-third of the rated capacity. If, however, the service is especially severe, calling for the movement of heavy trains at high speeds, or up long grades, it is necessary to use a system of forced ventilation. This is accomplished by taking the air from the side of the locomotive through a screen by means of a small high-speed blower, which delivers the air into a header from which connections are made to the frames of the motors.

MECHANICAL CONSTRUCTION.

The possibility of equipping each axle with its own power, thus avoiding connecting rods and long rigid wheel base, makes it feasible to adopt a very simple and flexible construction in the design of the trucks and running gear of the electric locomotive. The tendency in electric locomotive design has been in the direction of the swivel truck type, each unit having two such trucks, and each truck as a general rule being equipped with two electric motors. In the smaller sizes of locomotives or where the speeds are low, a two-axle truck is usually adopted, each axle being equipped with motors, but in the larger sizes of locomotives, or where speeds of 60 to 75 miles per hour are to be attained, the construction

often recommended consists of a four-axle truck, the two inside axles being the driving axles and equipped with motors, and the two outside axles being used for guiding. Each truck is swiveled on center plates of ample size to transmit the tractive effort. The trucks are symmetrical, with the weight largely concentrated near the center, and as the outer ends of the truck are relatively light, the truck as a whole has small turning inertia, and is easily controlled by the guiding wheels

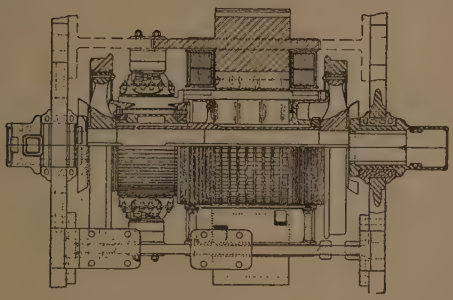


Fig. 154. Longitudinal Section of Bipolar Gearless Direct Current Motor.

without producing strains liable to affect the track alignment. The draw heads are attached to the locomotive frame, leaving the trucks free to follow curves, or any inequalities in the track.

In heavy freight service, it is sometimes proposed to use an articulated construction, consisting of two three-axle, or two four-axle trucks, connected together by a hinged or articulated coupling, thus reducing the rigid wheel base. In this type the cab may consist either of

a single rigid structure mounted so as to permit lateral movement of the truck, or it may be constructed in two sections, each mounted rigidly on its truck, the two sections being connected flexibly together.

While as a general rule these types may be made to cover all conditions of heavy freight or passenger work, occasion may arise where other designs may for various reasons, such as possible reduction in cost or concentration of large power in one unit, be found desirable. The

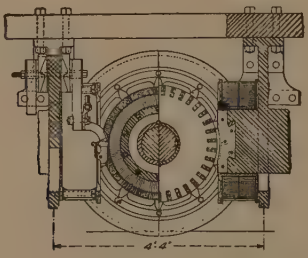


Fig. 155. Transverse Section of Bipolar Gearless Direct Current Motor.

latter requirement, however, is of small importance from the fact that the system of control adopted for electric locomotives will permit two or more machines to be coupled together and operated by the engine driver as a single unit from any section.

Following is a short description of the type of electric locomotives in service on the New York Central & Hudson River Railway:*

*To Mr. J. C. Irwin and Mr. S. A Bickford, both of New York Central, are due thanks for completeness of the following information.

At each end of the locomotive is a swiveling truck with one axle; these axles carry 36 inch wheels. From the last driver axle to truck axle is 7 feet, and from truck axle to end of locomotive is 5 feet more. This with the 13 foot driving wheel base gives a total length of 37 feet, or 30 feet shorter than a steam locomotive.

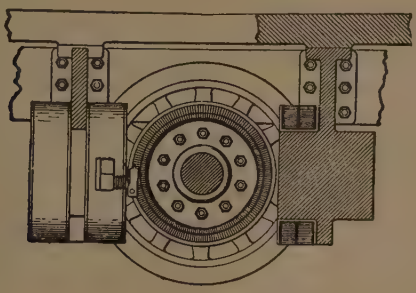


Fig. 156. Locomotive Motor.

Each driving axle is 8½ inches in diameter and has keyed to it a sleeve upon which is carried the armature core sleeve and the commutator hub, each separately keyed. The drivers are forced on the axles as usual, forming a rigid and solid unit.

Fig. 156 shows one of these units standing inside its field coils with one driver removed to afford a better view.

The top bar is not a mechanical part of the frame, but is one of the two pieces of soft steel, running the length of the motors to improve the conductivity of the magnetic circuit.

Since the commutator ends of the motors are the lighter, these bars lie on that side of the frame, preserving a mechanical balance.

This bar shown in Fig. 157 runs the length of the four motors.

In Fig. 156 the broad piece below the bar is the locomotive frame, which together with the transoms acts as the main magnetic circuit. The transoms are bolted to the frame as shown.

The five transoms in the middle of the frame carry bosses which serve as magnet cores and the field coils are placed on them.

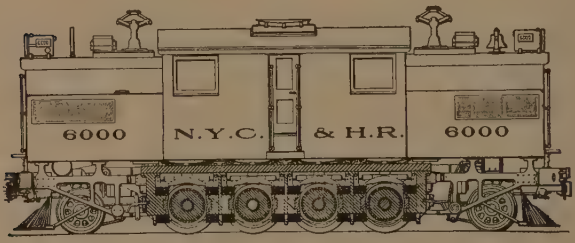


Fig. 157. The First New York Central Locomotive.

The pole face, not shown in Fig. 156, but in Fig. 157, is of soft iron sheets held between two heavier end pieces, dove-tailed to the magnet core and keyed. These prevent the field coils from slipping off.

The ordinary motor has a cylindrical pole face, but these are almost flat, so that the armature can stay still on the track, and the frame with the poles swings up and down without striking the armature. This shape also makes it possible to drop an armature down into a pit without disturbing the pole faces, or field coils.

The brush holders being on the transoms, move up and down with the frame, being kept in contact with the commutator by springs.

The collector shoes are also fastened to the frame, being kept on the third rail by springs.

The field coils are 80 turns of copper ribbon 3 inches wide, insulated by card board. They are wound on a brass spool which is slipped into a shell, and the protection completed by riveting the joints, and pouring the shell full of a bituminous compound.

The journal bearings each have a pedestal resting on them which carries on its upper end a half elliptic spring. The bearings slide in jaws of the frame.

The weight of each pair of drivers, the axle, the complete armature, journal bearing, pedestal and spring, rest solidly on the track. The two trucks do the same.

Everything else rests on the frame, and the frame is hung from the springs.

The two trucks and the drivers furnish six axles to support the weight of the frame and its load.

Equalizing levers distribute the load properly, and cross equalizers give a three-point support.

The superstructure consists of the cab in the center, and two end compartments.

In the center of the cab stands the steam heating apparatus. A kerosene automobile burner heats a coil tube boiler, producing superheated steam. This, when passed through a reducing valve furnishes to the train absolutely dry low pressure steam. In this way the size of plant capable of heating a train is reduced to a minimum. The fuel, and water pumps are motor driven.

At one end of this heater is the motor driven air compressor. There are two motors on its shaft connected in series. This gives 300 volts per motor and enables them to run at the low speed of 175 R. P. M. The compressor supplies 130 lbs. of air for braking, whistling, bell ring-

ing, and sanding. It is regulated by a starting and stopping switch which is opened and closed by an electro magnet. This magnet is operated by a switch, opened and closed by the action of the air on a diaphragm. 125 lbs. pressure starts, and 135 lbs. stops the motors.

At both corners diagonally opposite, are duplicate sets of controlling apparatus. They consist of the controller bar, and reverse lever under the left hand. In front are the automatic and straight air brakes, the hand sander, the ammeter and air gauge, and the control circuit switch. At the right hand is the air blast sander, bell and whistle valves.

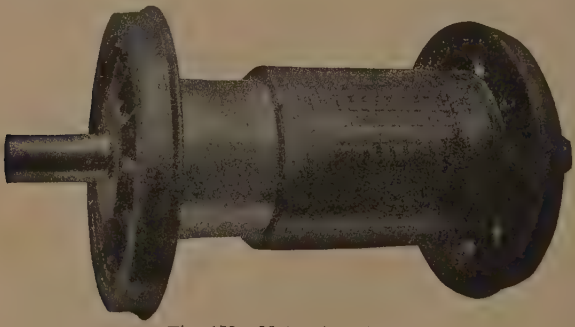


Fig. 158. Motor Armature.

The end compartments contain a central aisle, and on either side in asbestos lined sheet steel cabinets are contained the other apparatus of the control.

Each of these four cabinets (two at each end) contains the resistances and the contactors for one motor. Evenly distributed among the four are the two reversers, the main power switch, the circuit breaker, the throttle relay,

air pressure governor, air sanders, and the contactors for motor combinations.

The lighting and head light switches are in the aisles for ready access.

A view of a complete armature mounted on driving axle is given in Fig. 158.

The locomotive is fitted with the Sprague-General Electric Type M Control, with a controlled acceleration.

There is a friction clutch attached to the main shaft of the controller, operated by a magnet. This magnet is in the circuit of wire 18, which also contains a magnetically operated switch.

The operating coil of the switch is a part of the main power circuit leading to motor No. 2.

When the motor is taking less than 900 amperes from the line the magnet is too weak to close the switch, and so the locking coil is not energized, and the controller handle is free to be moved.

Should the motor current rise above 900 amperes the magnet closes the switch, the lock coil throws the clutch and the engineer can not advance the handle until the current falls to its normal value.

Fig. 159 shows the wiring of the four motors, their resistances and contactors as arranged in the New York Central locomotive No. 6000, the first one built.

The terminals marked T are connected to the third rail or "trolley," those marked R to the rails or return circuit, often called "ground."

The armatures are represented by circles and the fields by squares. The resistances are shown by the crooked lines, being a rough imitation of the shape of the cast iron grids used as resistances.

On No. 1 motor at the top has been indicated how the

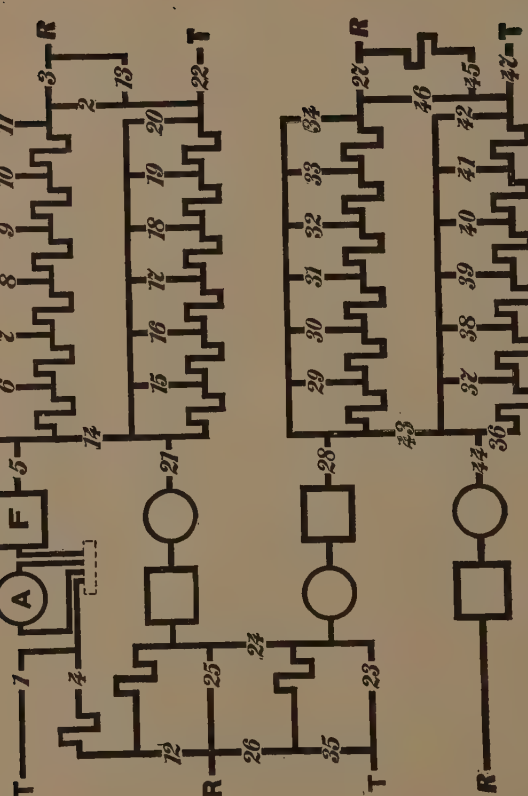


Fig. 159. Diagram of Motor Control New York Central Locomotive.

leads go to a reverser, but this has been omitted from the rest of the diagram for the sake of clearness.

Each number represents a *contactor,* and when the contactor is closed the gap in the circuit as shown in the diagram is closed, and the current is permitted to pass.

The wiring which actuates these contactors is called the *control system* and will be the subject of another illustration. This diagram (Fig. 159) only shows the main or power circuits. Each wire in the *control* is numbered and this number is used to refer to it.

The controller which actuates these 47 contactors has 24 positions or *notches* numbered consecutively. Nos. 10, 17 and 24 are running positions, placing the motors at N 10 all in series; at N 17 in series-multiple; i. e., two in series and two in parallel or multiple; at 24 all in multiple. This gives quarter, half, and full speeds. At all the other notches there is more or less resistance in the circuits, and the controller must not be left permanently at any notch but these three.

The motors are numbered from the top of Fig. 159 down, Nos. 1, 2, 3 and 4. The numbers 1, 2, 3 and 4 after a symbol denote the motor to which the part belongs.

F 1 denotes the field of motor No. 1. R 12 denotes the second resistance (counting from left to right) of the first motor. R 36 denotes last resistance of third motor.

Each motor has a set of six resistance grids, whose total for each motor is 0.4 ohm, and whose parts have resistances as given in Table A. In Table B is given the resistance left in each motor circuit when the previous grids are cut out.

TABLE A.

Resistance	1=0.120 ohm.
Resistance	2=0.085 ohm.
Resistance	3=0.055 ohm.
Resistance	4=0.050 ohm.
Resistance	5=0.046 ohm.
Resistance	6=0.044 ohm.

TABLE B.

Resistance	1 to end=0.40 ohm.
Resistance	2 to end=0.28 ohm.
Resistance	3 to end=0.195 ohm.
Resistance	4 to end=0.14 ohm.
Resistance	5 to end=0.09 ohm.
Resistance	6 to end=0.044 ohm.

There are four other resistances, one per motor, located as follows:

B 1 between contactor 4 and R.
B 2 between F 2 and 12.
B 3 between A 3 and 35.
B 4 between 45 and R.

These resistances are 0.48 ohm each. B 2 and B 3 are used as *bridge* resistances to prevent short circuits when changing from slow to middle speed. B 1 and B 4 are used as resistances during electrical braking.

Fig. 160 shows the electrical connections of a locomotive reverser.

The right and left sides are exact duplicates, so only one side will be described.

As shown the S portion of the reverser is shut, and the O part is open. The magnets and link bars operating the two pairs of toggles S and O are left out, in order to make the diagram more simple.

T represents a tap from the main power cable, and may be considered as "*trolley.*"

The current comes from T, goes through B to the armature *a* (circle), thence to C and passes through the field *f* (square). The same thing happens on the other side of S.

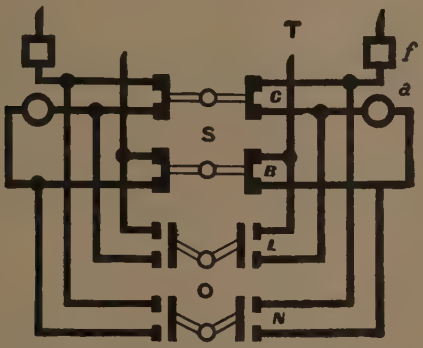


Fig. 160. Diagram of Locomotive Reverser.

If, however, the magnet connected to O is energized, the toggles O will straighten and close the contacts L and N on both sides. The magnet S being interlocked with O is now de-energized, and the S toggles loosen and contacts C and B open.

Then the current goes from T to L and through the armature in *opposite* direction than before, thence to N and through the field in the same direction as before. The motor now reverses.

OPERATION OF CONTROL.

The controller levers are not removable, and for the purpose of this explanation they are assumed to be both in place in the off position. There is but one reversing, and one air wrench with each locomotive, and in order to remove the reversing wrench, it is necessary that the controller levers be in the off position. Likewise it is necessary that the air brake wrench be at lap position before it can be removed. The first work of the engineer is to move the reversing wrench to forward position. This puts wire 8 to trolley and ground (T and R), and the control current passes through the reverser magnets, and pulls both to the forward position.

Wires 41 and 42 now close contactors 1-5-21 and 28-44-36. These are *always* closed while the locomotive is running.

Notch 1 now energizes W 1, closing C 2-24-46, completing a series circuit of the four motors and 1.6 ohms resistance.

For the next nine notches these contactors remain closed, and in addition other contactors close and open as follows:

Notch 2 energizes W 6, closing C 20, cutting out all of the resistance belonging to M 2, thus reducing the total extra resistance to 1.2 ohms.

Notch 3 energizes W 7, which picks up C 20 (which W 6 no longer holds) and also C 42, which cuts out 0.4 ohms more, reducing resistance to 0.8 ohms.

Notch 4 energizes W 10, which holds up C 20 and 42 and also closes C 34, cutting out 0.4 ohms more.

Notches 5-6-7-8-9: While W 10 continues to be energized holding C 20-34-42, wires 11-12-13-14-15 are suc-

cessively energized, closing C 6-7-8-9-10 one after the other. Thus gradually reducing the resistance from 0.4 to 0.044 ohms, as shown by Table B. Each contactor stays down until the following one closes.

Notch 10: Wire 16 is energized and W 10 de-energized, but C 20-34-42 are held up by W 16 and it picks up C 11 in addition, thus putting the motors in full series between Trolley 1 and Return 4, without resistance. N 10 is a running position at a slow speed.

In moving from N 10 to N 11 many changes occur. W 41 and 42 are of course still working. W 5 cuts in and transfers C 2 and 46 from W 1 to itself, it also closes C 12 and 35. The two bridging resistances B 2 and B 3 being together equal to 0.96 ohms prevent a short circuit from T 3 to R 2.

The circuit containing B 2 is called a *bridge* because it bridges over what would otherwise be an opening in the circuit as the changes occur.

W 1 now drops out of circuit, allowing C 24 to open, thus placing two motors in series between T and R.

W 2 is now energized and closes C 25 and 23, cutting out B 2 and B 3, considerably reducing the resistance of each motor combination.

W 10 now closes C 20 and 42, but *not* C 34 as it did before. W 10 can only shut C 34 if C 24 is already closed. This is due to a system of interlocks. C 24 is now open, for it dropped when changed from W 1 to W 5.

The motors are now in series—multiple with half of the resistance in series.

Notches 12 to 17 (both inclusive) energize in succession W 11-12-13-14-15-16, closing C 6 and 29, then C 7 and 30, etc., thus stepping out the remaining resistance

until at N 17 there is a free running position with no resistance in.

Between N 17 and 18 a change is made from W 2 to W 3 which performs same duties as W 2 and in addition closes the bridges C 14 and 43. These two contactors produce no electrical changes, for the resistances were already cut out entirely by W 16 through the contactors under its control.

W 16 can now be and is dropped without any electrical change. W 4 is now energized closing C 3-22-27-47. There are no short circuits caused, because between trolley and return on one side of the bridges are the motors, and on the other side are the double resistances, each 0.8 ohms.

W 2 is again taken up, which takes care of C 24-25, holding them up, and W 2 is dropped, letting go of C 14 and 43.

The motors are now in multiple, with resistance in series.

Notches 19 to 24 keep W 2 and 4 energized and successively energize W 11-12-13-14-15-16, closing contactors four at a time, i. e., C 6-15-29-37, then C 7-16-30-38, etc., until finally W 2-4-41-42 and 16 keep the contactors closed for free full multiple running.

The spaces between N 10 and 11 and N 17 and 18 are wider than the others to give room for enough motion to make the desired wire changes. These spaces must be passed over by a continuous motion of the controller arm.

Wires 11 to 16 always close contactors four at a time, but the first and second times they are used, part of the contactors closed produced no electrical changes, and for simplicity mention of the fact was omitted.

Contactors 4-26-13-45 are used when braking electrically in this way.

A switch called a commutating switch is thrown and the controller pulled to first notch.

The commutating switch brings in wires 17-4 and 5, W 17 closes contactors 4-13-26-45.

W 4 and W 5 due to interlocks do not close as many contactors as they would if energized through main controller, so W 4 only closes 3-27 and W 5 only closes 12.

Notch 1 of controller energizes W 41 and W 42. W 42 as usual closes 28-36-44 while W 41 on account of interlocks only closes 5 and 21. The four motors are now in parallel across the track rails, all connection with third rail being cut off. They now act as generators and act as brakes.

This can only be done when one locomotive is on a train, owing to the fact that the other locomotive being so near (40 feet) acts as a short circuit.

The one wire not mentioned, W 18, is the one called controller lock. It energizes the magnet of the friction clutch through a relay whenever current input exceeds 900 amperes per motor.

Table C gives the number of the control wire, the contactors operated by it, and the notches of the controller making use of the wire.

In this table and elsewhere 1 to 10 means both inclusive and 1-2-10 means separate numbers.

GENERAL.

The remarks pertaining to the Sprague-General Electric type "M" control will also apply to the electric locomotive control, except that the train cable in the

locomotive control has twenty wires, seventeen of which are connected to the master controller and to the motor control apparatus. Of the remaining three wires two are used for the sander device, and one is an extra. This control, in the same way as on the Suburban Motor Cars, comprises two distinct sets of circuits, namely, the main or motor control circuits, and the master control motor circuits, the former being governed by the latter. Each locomotive has four motors, the control being arranged for operating the motors first, all in series, then in series parallel, and then in parallel relation. The two ends of locomotive are designed the "A" end and the "B" end, the main switch being located on the "B" end.

The Motor Control on each locomotive consists of the following apparatus:

Contactors.
Reversers.
Rheostats.
Main switch.
Main motor cut-out switches.
Individual motor fuses.

In addition to these pieces of apparatus there are four sets of third-rail contact shoes (two shoes in each set) and two overhead contact shoes, with the necessary main cables connecting them to the control apparatus on the locomotive. There is also a main cable extending through the locomotive, terminating with couplers at the ends, so that the third-rail shoes, and the overhead shoes of any two or more locomotives may be connected together. This cable is termed the Bus Line. The circuits from the contact shoes (both third-rail and overhead) are protected by fuses, a set of two fuses in multiple being located near each shoe to protect the circuit of that shoe.

From the third-rail shoes, or from the overhead shoes the main circuit is carried through the respective fuses of each to the main switch, and through the motor fuses to the contactors and thence to motors.

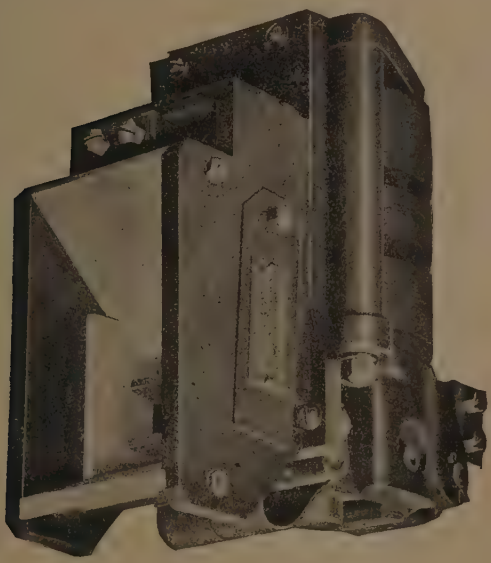


Fig. 161. Contactor for Heavy Current.

The Contactor (Fig. 161) is an electro-magnet switch, with two contact arms, and sets of contacts in multiple operated by one plunger. There are 43 of these contactors which are located in the end compartments of the cab, one group on each side of each end compartment. The contactors are suspended by insulating bolts

from channel iron supports. The contactors are numbered progressively around the cab, No. 1 being the nearest the No. 1 reverser. Each contactor has a plate with its number, which is attached in front above the arc chute.

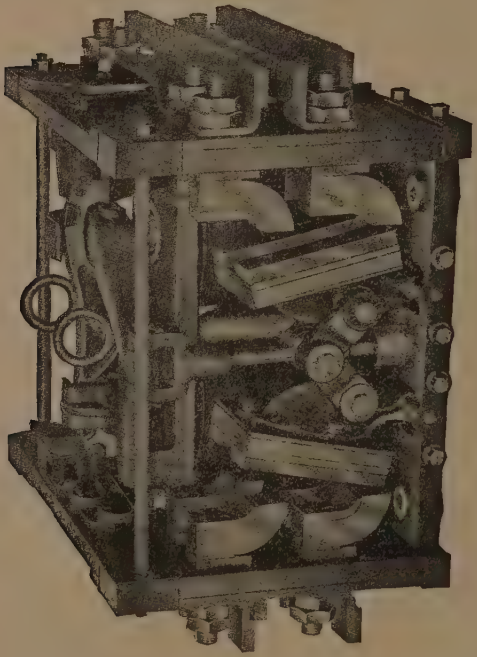


Fig. 162. Reverser for Locomotive.

Reverser (Fig. 162). There are two reversers; one in each end compartment. The No. 1 reverser, which is on the main switch end of the locomotive, has the arma-

Fig. 163. Grid Resistance.

ture and field leads of the two motors on that end connected to the studs of its contact brushes. The connections of armatures and field leads for producing forward, and backward movement of locomotive are established by means of copper bars pressed against spring contact brushes, through a toggle mechanism.

The Motor Control Rheostats (Fig. 163) are similar to those already described. These rheostats are located in four groups on the floor in end compartment of cab, under the contactors.

The Main Switch (Fig. 164) is a knife-blade, quick-break switch, with a lower mechanism for operating. The switch itself is enclosed in a box, lined with fire-proof insulation, the handle for operating being located outside the box, where it is readily accessible. This switch is located in "B" end compartment of cab. It should not be opened while current is on motors, except in an emergency. It should, however, be opened before the individual motor fuses, or contactors and reversers are examined.

Main Motor Cut-Out Switches (Fig. 165) are for the purpose of cutting out the individual motors in case of any ground, or defect in a motor which renders it inoperative. There are four of these cut-out switches, one for each motor, and they are located on the sides of the cab, the switches for No. 1 and No. 2 motors being just over the No. 1 reverser and for No. 3 and No. 4 motors over the No. 2 reverser. The number of the motor to which it is connected is marked on each switch. Each switch also has a small auxiliary control cut-out switch which opens, and closes with the larger switch for operating the circuit of the series contactor coils. These switches are normally kept closed, except in case

Fig. 164. Main Switch.

of individual motor trouble. It should be seen that they are well closed, so that the small auxiliary switches make good contact. When one of these switches is

Fig. 165. Main Motor Cut-out Switches.

opened on account of motor trouble, the locomotive will not move until controller handle reaches the eleventh notch.

Motor Fuse Box (Fig. 166). There are four of these fuse boxes, each motor having its individual fuse. These boxes are located one over each third-rail shoe, just above

Fig. 166. Motor Fuse Box.

Fig. 167. Third Rail Shoe Fuse Box.

the shoe fuse boxes. A copper ribbon fuse of 800 ampere rating is used in these boxes. Each box has marked on it the number of the motor whose circuit it protects.

Third-Rail Shoe Fuse Boxes (Fig. 167) are similar

to the motor fuse boxes, but somewhat larger. There are two of these arranged in multiple for each pair of third-rail shoes and are mounted on brackets just above their shoes. Copper ribbon fuse of 1,600 ampere rating is used in each of these boxes.

Overhead Shoe Fuse Boxes are practically the same as those for third-rail shoe, but are mounted on the roof, two in multiple near each other. A copper ribbon fuse of 1,600 ampere rating is used here also.

Third-Rail Contact Shoes. These shoes are of the "Slipper" spring actuated, under-running type. The shoe bracket is mounted on a wooden insulating beam. There are two shoes in multiple on each bracket.

Overhead Contact Device (Fig. 168) is a pneumatically operated shoe. There is a valve near each master controller in the cab, by means of which the shoe may be raised or lowered. When air is applied, the shoe is lifted so as to make contact with the overhead rail. When air is released the shoe drops; also if the shoe runs off the rail it is stripped automatically, and drops. Moving the handle forward operates a pilot valve, by means of which a slide valve is thrown to admit air from the reservoir, to the cylinder of contact shoe device. Pulling the handle back operates another pilot valve, and the slide valve is thrown over to connect air chamber of contact device to exhaust. The handle will spring back to the middle position from either direction. There are two of these overhead contact shoes, which are controlled in common by either valve in the cab. They are mounted on wooden insulating blocks. It is very important that these shoes should not be raised when they will come in contact with overhead obstructions.

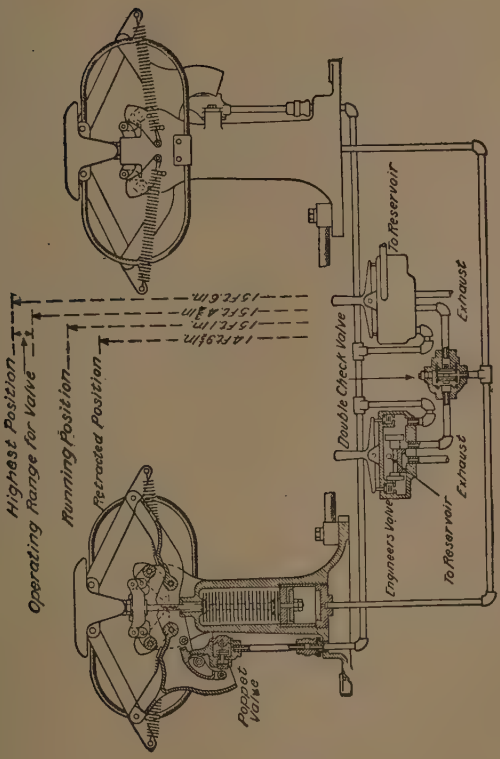


Fig. 168. Overhead Contact Device.

The Bus Line Coupler Socket (Fig. 169) has three split plug contacts, which are connected together for obtaining sufficient carrying capacity.

The Bus Line Coupler or Jumper is shown in Fig. 170.

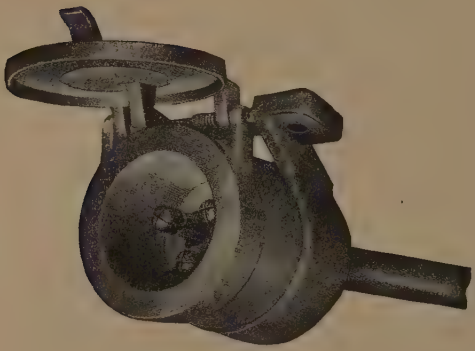


Fig. 169. Bus Line Coupler Socket.

MASTER CONTROL.

The Master Control Apparatus comprises the following for each locomotive:

Two master controllers.
One main master controller switch.
Two overhead master controller switches.
One negative control switch.
Train cable.
Four train cable coupler sockets.
One train cable coupler or jumper.
One train cable connection box.
One train cable cut-out switch, combining also a second train cable connection box.
One current limit relay.
Control fuses.

The Master Controller (Fig. 171) contains two movable cylinders, which are geared together, and stationary

Fig. 170. Bus Line Coupler or Jumper.

contacts for each, mounted on insulation supports. The function of the controller in general is to supply current at the will of the engineer, to the train cable for operating the reversers and contactors. The primary or slow-

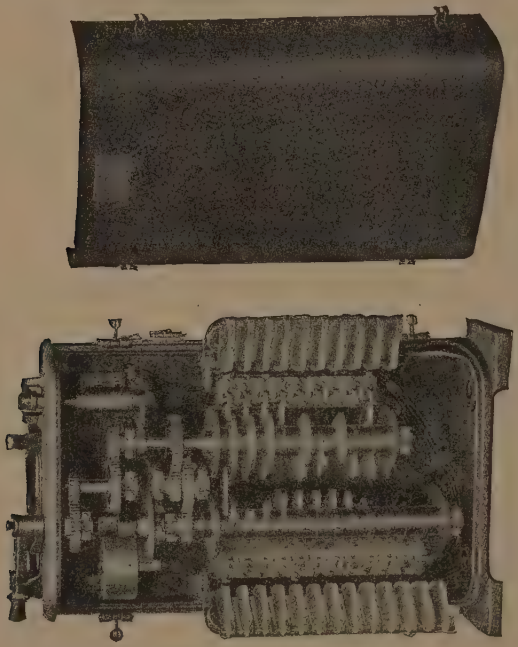


Fig. 171. Master Controller.

speed cylinder operates the contactors which produce motor combinations. The secondary or high-speed cylinder operates those contactors which cut out the main motor resistance. The secondary cylinder is geared to

the primary at the ratio of about three to one. Geared to the cylinders is a governor device, by means of which the movement of the controller handle, and the cylinders is checked when current through the motors exceeds a certain amount. The controller has a separate reverse cylinder, and there is a separate handle for this. The reverse handle can be thrown, only when the controller handle is in the "off" position. The "off" position of the controller handle is indicated, and is the extreme forward position of the handle. There are twenty-four operating notches and an "off" point on the controller dial ring. A latch on the handle engages the notches on the dial ring, and has to be released in moving from notch to notch. The first ten operating notches are for series, the next seven for series parallel, and the next seven for parallel operation of motors. The tenth notch is full series, the seventeenth full series parallel, and the twenty-fourth full parallel position of motors, and at all other points, motors will have resistance in circuit.

Main Master Controller Switch (Fig. 172) is located on side of passage way in "B" end compartment of cab, and is used for admitting current to master controllers, and should be closed to operate from either master controller. The main purpose of this switch is to cut off the line from the master controller fuse, which is located in this switch, in case the fuse has to be inspected or renewed. The fuse for this switch is 25 ampere capacity.

The Overhead Master Controller Switches (Fig. 173) are located one over each master controller and are used for admitting or cutting off current from the controller over which it is located.

The Negative Control Switch (Fig. 173) is located on the side of the passage way of the "A" end. Opening

Fig. 172. Master Controller Switch; Pump Switch; also Main Sander Switch on Locomotive.

this switch cuts off ground from the reverser and contactor coils. It must be kept closed for operation. Ordinarily it need not be touched.

The Train Cable is composed of twenty conductors, which are attached to numbered plugs in the coupler

Fig. 173. Master Controller Switch Without Fuse. Also Negative Control Switch on Locomotive.

sockets, and there are branches from seventeen of these wires extending to the master controller. These seventeen wires are used as follows:

No. 1—For operating series contactors.

Nos. 2 and 5.—For operating series-parallel contactors.

No. 3.—For operating bridge contactors.

Nos. 2 and 4.—For operating parallel contactors.

Nos. 6, 7, 10, 11, 12, 13, 14, 15 and 16.—For operating resistance contactors.

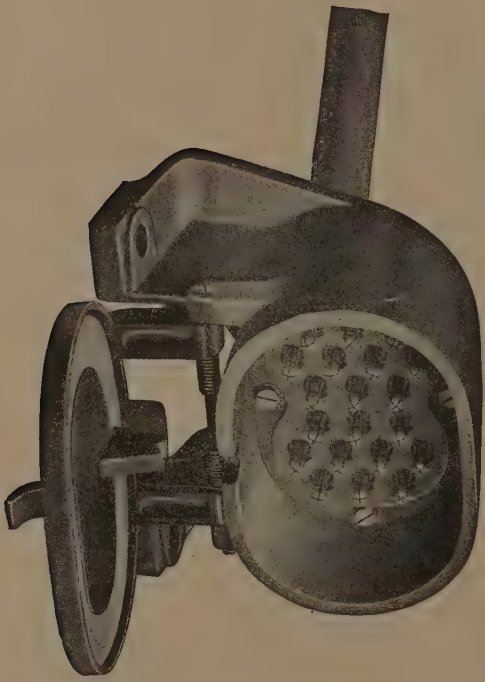


Fig. 174. Train Cable Coupler Socket.

No. 18.—For operating controller governor.

No. 0.—For operating reverser one direction.

No. 8.—For operating reverser other direction.

Fig. 175. Train Cable Coupler Plug.

Nos. 19 and 20 are used for operating the sander device.

No. 17 is an extra wire.

The Train Cable Coupler Socket (Fig. 174) has twenty contact studs.

The Train Cable Coupler Plug (Fig. 175) has twenty contacts to agree with coupler socket.

Train Cable Connection Boxes are used for making connections from master controller and coupler sockets to the train cable. One of these connection boxes (Fig. 176) is combined with the twenty-point cut-out switch. This is mounted on the back of the master controller on the "A" end of the cab. This is the No. 2 connection box. The plain connection box (Fig. 177) is mounted on the back of the controller at "B" end of the cab. No. 0 wire from No. 1 box connects to No. 8 wire in No. 2 box, and No. 8 from No. 1 box connects with No. 0 in No. 2 box. All other wires connect number to number. One of the wires in the outside layer is covered with green braid. This is No. 1 wire, the other wires of this layer being numbered in the counterclock-wise direction from this. The red covered wire in the inner layer is No. 14, the others being numbered counterclock-wise direction.

The Current Limit Relay (Fig. 178) is located just above the No. 1 reverser and is provided for the purpose of checking a too rapid movement of the controller handle in getting the train up to speed. The relay coil is connected in series with No. 2 motor circuit. If the current through the motor exceeds a certain amount, the relay plunger picks up, and closes a set of contacts which supplies current to the controller governor. The controller handle is thus held from being moved on, and

Fig. 176. Train Cable Connection Box.

cannot be moved another notch until the current through the motor falls to a certain amount.

The Control Cut-Out Switch (Fig. 176) has already been referred to under the subject of *Connection Boxes.* The connection studs of this box also serve the purpose

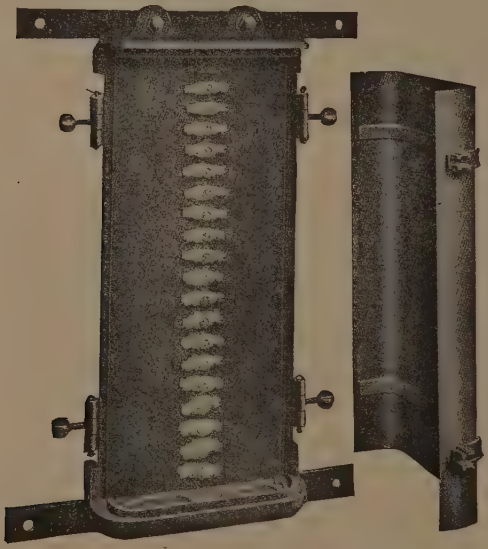


Fig. 177. Plain Connection Box.

of the No. 2 connection box. This cut-out switch serves the purpose of disconnecting the control circuits of contactors, and reversers on a locomotive from the train line. The cut-out switch has twenty sets of contacts which are connected, or disconnected accordingly as the handle is full around to the left or to the right.

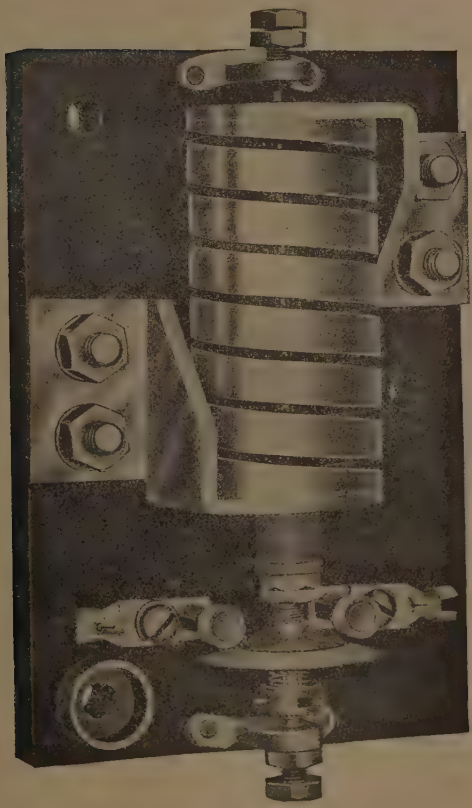


Fig. 178. Current Limit Relay for Locomotive.

Control Fuses (Fig. 176) are mounted on the same insulation back as the cut-out switch, and are contained in the same box. The fuses numbered from the top protect the following circuits:

No. 1—Series contactor coils.

Nos. 2 and 5—Series parallel contactor coils.

Nos. 2 and 4—Parallel contactor coils.

No. 3—Bridge contactor coils.

Nos. 8 and 9—The reverser operating coils.

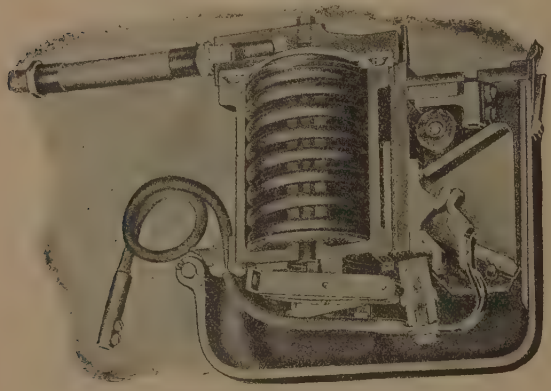


Fig. 179. Sectional View Air Pump Governor.

Nos. 6, 7, 10, 11, 12, 13, 14, 15 and 16—The resistance contactor coils, respectively, one fuse protecting the contactor coils for each resistance step of controller.

No. 17 is not required, but is extra.

No. 18—Controller governor circuit.

Nos. 19 and 20—Sander circuits.

AIR-COMPRESSOR CONTROL.

The air-compressor control comprises the following pieces of apparatus:

A pump motor switch.

A pump governor.

A pump motor circuit contactor.

Pump Motor Switch (Fig. 172) is located on the side of passage "A" end compartment. This switch is for the purpose of opening the pump motor circuit when locomotive is not in service. This switch contains a 40-ampere fuse, which protects the pump motor circuit.

Pump Governor (Fig. 179) is located in "A" compartment on side opposite No. 2 reverser. The governor is of the diaphragm type of construction, the movement of the diaphragm, as air pressure falls or rises, operating a lever mechanism which serves to give a quick make, and break to a small switch of the contactor type. This switch does not close the pump motor circuit itself, but closes the circuit through the *Pump Motor Circuit Contactor,* which has higher current capacity on its contacts than the governor. This contactor is located to the left of the governor. When the air pressure in the reservoir falls to 130 pounds, the governor closes its contacts, thereby energizing the contactor coil, which in turn closes its contacts; the pump motor circuit being thus completed, the pump starts. When the air pressure reaches 140 pounds the governor opens the circuit of the contactor coil, which in turn opens and breaks the pump motor circuit and the pump stops.

But the governor and the contactor have strong magnetic blow-outs at their contacts, sufficient to handle any current which they may take in this service.

TRACK SANDER CONTROL.

The track sander control comprises the following pieces of apparatus:

One main sander switch.

Two sander operating switches.

Two electro-pneumatic valves.

Fig. 180. Sander Operating Switch.

Main Sander Switch (Fig. 172) located in the "A" end compartment of cab, is for the purpose of admitting or cutting off current from the sander operating switches. This switch contains a 10-ampere fuse. The switch should be opened when inspecting fuse. This switch has a plate marked "Sander."

Sander Operating Switches (Fig. 180) are located one on each side of cab near each master controller. These

are double-throw switches and are marked "Sand Forward," "Sand Reverse." Moving handle to the "Forward" position energizes the valve which will apply sand to rail for forward direction. "Reverse" position of handle will apply sand for the reverse direction.

Fig. 181. Electro-Pneumatic Sanding Valve.

Electro-Pneumatic Valves (Fig. 181) are located one in each end compartment. One valve operates a sander for one direction of movement, the other valve operates a sander for the other direction, only one valve being

operated at a time. The valve is operated by a magnet which is energized by current applied in the sander operating switch.

TRAIN OPERATION—GENERAL.

Before attempting to start the locomotive the motorman should first close the pump switch, then close the main switch and see that the main control switch and all the cut-out switches are closed. After the reservoir and train line are charged the overhead control switch over the controller, from which the locomotive is to be operated should be closed, and the reverser handle thrown in the direction of desired movement of locomotive. The motorman may then proceed on the signal.

After releasing the latch on controller handle, pull controller handle to the first notch, then to the second notch, and so on, until the desired speed is attained. For coupling, with the locomotive, light, the first or second notches will ordinarily be sufficient. If it is desired to get up to speed as soon as possible the handle may be moved around notch by notch, allowing the latch to take each notch until the last notch is reached.

If the motorman feels at any point, the further movement of the controller checked, he should not exert undue pressure on the handle—no more than is ordinarily required to move the handle from one notch to the next. Whenever the current through the motors is higher than a certain amount, the automatic governor acts, and stops the further movement of the handle. When the current falls to a certain amount the governor releases the controller cylinders, and another notch may be taken, and so on. Every notch on the controller should invariably be taken by the latch in moving controller on, whether in

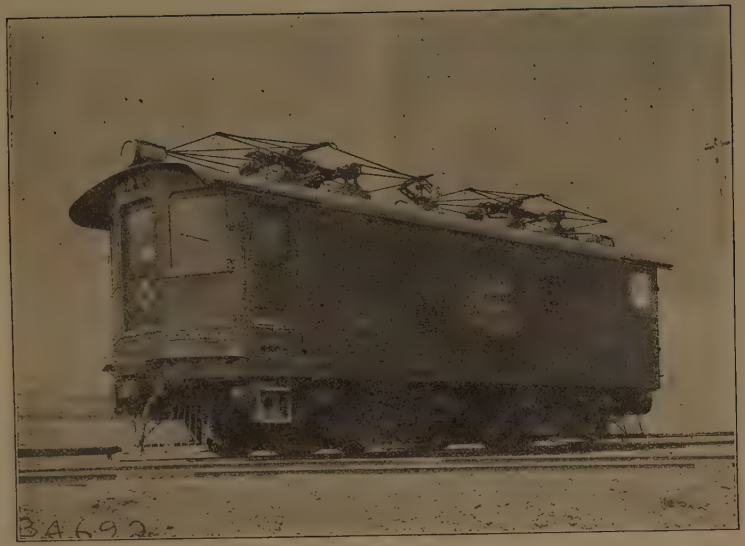


Fig. 182. New Haven Locomotive in D. C. Zone. A. C. Trolleys Down. Third Rail Shoes Down.

accelerating or in throwing controller on with motors already up to speed. In throwing off, the notches need not be observed.

The "off" notch of the controller may be called the zero notch. The first closed position of the controller is the first notch, and so on, the tenth notch being the full series position, the seventeenth notch the full series parallel position, and the twenty-fourth notch the full parallel position. The tenth, seventeenth and twenty-fourth notches may then be called running points. The intermediate points are resistance points, and should ordinarily be used only for accelerating or switching. The tenth notch gives one-quarter speed, the seventeenth notch one-half speed, and the twenty-fourth notch full speed. The transition from the tenth to the eleventh notches and from the seventeenth to the eighteenth should be made promptly, without pause between.

When the controller is on any notch the current passes from the master controller switch, through the master controller of the train cable of one or two locomotives, and thence to the reverser operating coils and the contactor coils, which correspond to the given notch, as shown in the following table. This table gives the numbers of the contactors which are closed on each step of the master controller. The numbers that are underscored indicate the contactors which are closed on that step in addition to previous ones.

Controller Steps.	Contactors Closed.
1	1-2-4-19-22-25-33-41-42
2	1-2-4-18-19-22-25-33-41-42
3	1-2-4-18-19-22-25-33-39-41-42
4	1-2-4-18-19-22-25-31-33-39-41-42

Series.....5	1-2-4-5-13-18-19-22-25-26-31-33-34-39-41-42
6	1-2-4-5-6-13-14-18-19-22-25-26-27-31-33-34-35-39-41-42
7	1-2-4-6-7-14-15-18-19-22-25-27-28-31-33-35-36-39-41-42
8	1-2-4-7-8-15-16-18-19-22-25-28-29-31-33-36-37-39-41-42
9	1-2-4-8-9-16-17-18-19-22-25-29-30-31-33-37-38-39-41-42
10	1-2-4-9-10-17-18-19-22-25-30-31-33-38-39-41-42
First Bridge.	1-2-4-11-19-25-32-33-41-42
11	1-2-4-11-18-19-21-23-25-32-33-39-41-42
Series Parallel..12	1-2-4-5-11-13-18-19-21-23-25-26-32-33-34-39-41-42
Series Parallel..13	1-2-4-5-6-11-13-14-18-19-21-23-25-26-27-32-33-34-35-39-41-42
14	1-2-4-6-7-11-14-15-18-19-21-23-25-27-28-32-33-35-36-39-41-42
15	1-2-4-7-8-11-15-16-18-19-21-23-25-28-29-32-33-36-37-39-41-42
16	1-2-4-8-9-11-16-17-18-19-21-23-25-29-30-32-33-37-38-39-41-42
17	1-2-4-9-10-11-12-17-18-19-21-23-25-30-31-32-33-38-39-40-41-42

Second Bridge	1-2-4-12-19-21-23-25-33-40-41-42
18	1-3-4-19-20-21-23-24-25-33-41-43
Parallel....19	1-3-4-5-13-19-20-21-23-24-25-26-33-34-41-43
20	1-3-4-5-6-13-14-19-20-21-23-24-25-26-27-33-34-35-41-43
21	1-3-4-6-7-14-15-19-20-21-23-24-25-27-28-33-35-36-41-43
22	1-3-4-7-8-15-16-19-20-21-23-24-25-28-29-33-36-37-41-43
23	1-3-4-8-9-16-17-19-20-21-23-24-25-29-30-33-37-38-41-43
Parallel....24	1-3-4-9-10-17-18-19-20-21-23-24-25-30-31-33-38-39-41-43

If the reversers are not already thrown to the position corresponding with the position of the reverser handle, when the controller is thrown to the first notch, current will first pass through the proper operating coil to ground. After the reversers have reached the correct position interlocking contacts on each reverser cut off current to ground, and establish a circuit through three contactor coils. Moving the reverse handle does not operate the reversers, but simply arranges the contacts, so that when the controller is turned to the first position, reversers will be thrown in the proper direction. The operating coil for one direction on one reverser is in multiple with the corresponding coil on the other reverser, these two coils being controlled by one wire from the master controller, and protected by one fuse.

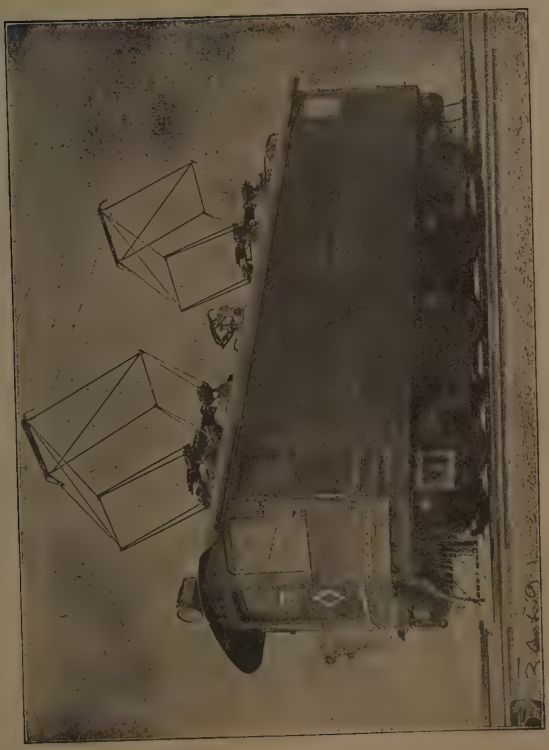


Fig. 182. New Haven Locomotive in A. C. Zone. A. C. Trolleys Up. Third Rail Shoes Up.

On the first notch the main or motor current flows from the third-rail shoes, or from the overhead shoes through the shoe fuses to the main switch, then through the No. 1 motor fuse, through the reverser and No. 1 motor, through a set of rheostats to reverser and No. 2 motor, then through the other reverser and No. 3 motor through a set of rheostats, then through another set of rheostats to reverser and No. 4 motor and then to ground. The four motors are here all in series, with all the resistance in circuit; and the locomotive, if light, may start, or if coupled to a train may simply take up draw-bar slack. Each of the next three steps cuts out one complete set of motor resistance, and on succeeding steps, until full series is reached, the remaining set is cut out in six more steps. After full series, between the tenth and eleventh notches, bridge connections are established, and then on the eleventh notch motors are thrown in series parallel relation. Resistance is cut out in six steps to full series parallel, the seventeenth notch. Bridge connections are then established and motors are then thrown all in parallel, the resistance being cut out again in six steps. When motors are in parallel each is protected by its own fuse.

When it is necessary to reverse the direction of train movement, leaving controller handle in the off position, throw the reverser handle in the opposite direction, and then move controller handle on in the same way. The reverser handle is to be thrown in the direction corresponding to direction of movement required. The motors should not be reversed while the locomotive is moving, except in case of emergency, and then the wheels would probably slip. If it is necessary to reverse while moving, do not throw the controller handle beyond the first notch,

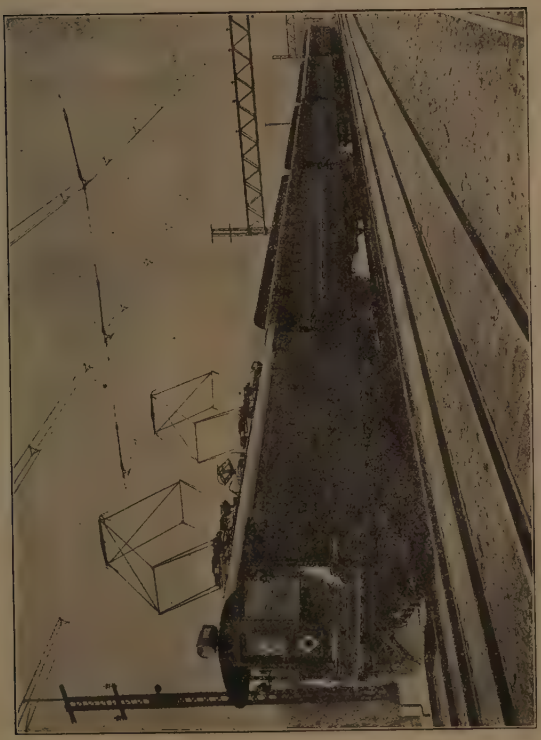


Fig. 184. New Haven Train.

if all the motors are cut in, or beyond the eleventh notch if one motor is cut out.

When operating on an overhead rail section, the overhead contact shoe will be tripped, and will drop, on leaving this section. The motorman should, however, as an extra precaution, throw the valve handle back. Either for raising or lowering the overhead shoe it is necessary to hold the handle in position only long enough for the shoe to start movement.

To sand the rails the *Sander Operating Switch* should be moved over in the direction of movement of the locomotive. To stop the sand the handle of this switch must be brought back to the middle position.

The control cut-out switch, if open, disconnects the operating parts of contactors and reversers on the locomotives from the train cable, but does not affect the operation of the other locomotive if two are connected together, although it is cut out on the locomotive whose master controller is being operated. The control connections for the reverser are so arranged that unless it is at the proper position, current is cut off from contactors, so that motors on that locomotive will receive no current. In case of electrical trouble within the master controller, train cable, couplers, or connections boxes, the single fuse in the master control switch will protect them. In case of local trouble on contactors or reversers the fuses in the cut-out switch will protect the circuit.

The electric locomotives in service on the New York, New Haven and Hartford Ry. were furnished by the Westinghouse Company. The overhead construction for the transmission of current on this line is supported from steel bridges which are located every 300 feet and which normally span from four to six tracks, although on

certain portions of the road longer bridges are employed. Every two miles the bridge is made of a specially heavy construction—forming an anchor-bridge to make the overhead structure even more secure. The trolley wires are hung from steel messenger cables which, in turn, are supported by heavy insulators mounted upon the steel bridges. Each trolley wire is suspended from a pair of steel messenger cables by triangular supports, forming a double catenary suspension of great strength and stiffness. The triangular supports are placed about ten feet apart. The messenger cables have a total sag of about six feet, while the trolley wire itself is held in a practically horizontal position.

The trolley system is divided into sections approximately two miles in length, each section being separated from its neighbors by heavy line insulators. Adjoining sections are connected through automatic oil-type circuit breakers. If a short circuit or other trouble occurs in any section, therefore, it can be cut out without disturbing the operation of other portions of the line. Two feeder wires are carried the whole length of the alternating-current line and are so connected to the various sections of the trolley system by automatic switches that any section of four or more trolleys can be cut out of service, and those beyond kept in operation.

The trolley wires are held normally at a height of 22 feet above the track. The overhead system is designed with a safe margin to meet the stresses imposed by the most severe conditions—such as high winds or heavy coatings of ice.

Following is a brief description of these locomotives, which are adapted to use either direct, or alternating current:

The frames, trucks, and cabs, of the locomotives were built by the Baldwin Locomotive Company, according to designs developed with the co-operation of the New Haven Railroad, and the Westinghouse Electric and Manufacturing Companies.

The Frame. As the entire space between the wheels is occupied by the motors, it was impossible to transmit the draw-bar pull through the center line of the locomotive; consequently the entire strain is carried by the strong plate girders which make up the locomotive frame. A Westinghouse friction draft gear is mounted directly underneath the box girder at each end and is applied to two steel bumpers laid horizontally between vertical gusset plates on the ends of the side channels.

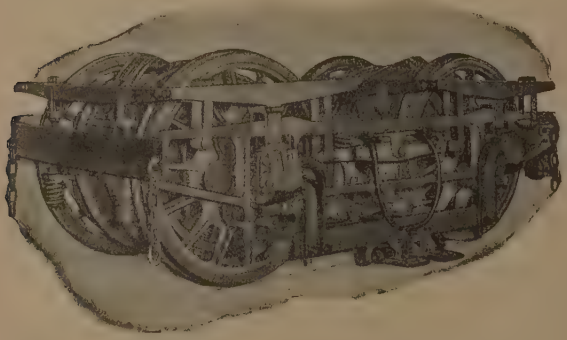


Fig. 185. One Truck of New Haven Locomotive.

The Trucks. The running gear consists of two trucks, each mounted on four 62-inch driving wheels. The trucks have side frames of forged steel to which are bolted, and

riveted, pressed steel bolsters which carry the center plates. The weight on the journal boxes is carried by small semi-elliptic springs with auxiliary coiled springs under the ends of the equalizer bars, to assist in restoring equilibrium. A very strong construction is secured, without excessive weight by the use of bolsters 30 inches wide at the center plate, and extended to nearly double that width at the ends which are bolted to the side frames. Center pins 18 inches in diameter transmit the tractive effort to the frame. They are well lubricated to permit free motion on curves. The truck pedestals are provided with wedge, and gib adjustments to take up wear, and the bearing brasses are easily removable by hand. The distance between truck centers is 14 feet, 6 inches.

Cab. The cab is formed of sheet steel mounted on a framework of Z bars which supports the walls and roof. Windows are provided at each end, giving an outlook on both sides and in front of the locomotive; and the driver is so close to the front that he can see the track a very few feet ahead. This advantage is not possessed by any type of steam locomotive now in service. The master-controllers, auto-transformers, instruments, grid resistances, air operating valves, compressors, and other auxiliary apparatus are mounted inside the cab upon an angle-iron framework which is built into the cab, and securely anchored to floor and roof. A clear passage-way is left through the center. Trap doors in the floor furnish easy access to the motors for inspection or repair.

Equipment. The equipment of the locomotive includes four gearless motors, controlling apparatus and auxiliaries.

Motors. The motors are of the gearless type, designed for operation on both single-phase alternating, and direct current. They are wound for approximately 235 volts on alternating current, and 275 to 300 volts when operated by direct current. They have normal rated outputs of 250 H. P. on the basis of ordinary railway practice, and

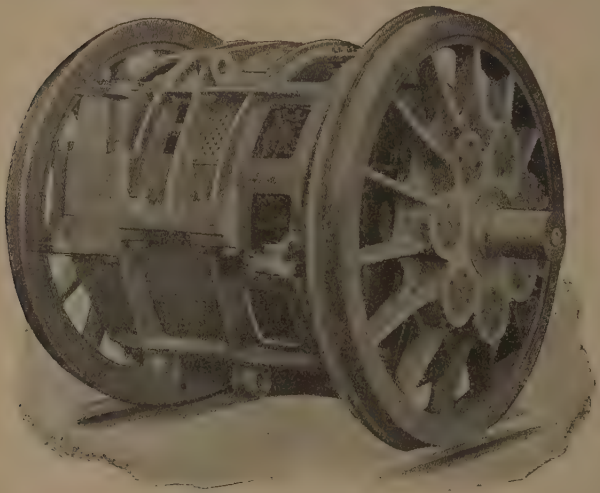


Fig. 186. One Complete Motor for New Haven Locomotive.

a continuous capacity of 200 H. P. each. The locomotive therefore, has a continuous operating capacity of 800 H. P.

The motor frames are made of cast steel, and are of a circular, skeleton form. They are divided horizontally into two parts in order to give access to the inside of the

field, or to the armature. A laminated core, with slotted projecting poles is built up within this frame, and wound with field coils of flat copper strap insulated between turns with asbestos, and filled with an insulating compound which is heat-conducting, and waterproof, so that a sealed coil is produced, which can withstand moisture, and internal heat. Copper bars are placed in slots in the pole faces, and connected to form a continuous neutral-

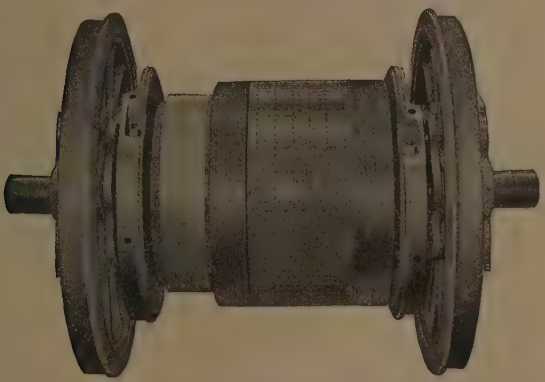


Fig. 187. Complete Armature Mounted on Locomotive Axle.

izing winding, which forms part of the circuit including the main field coils, the armature coils and the auxiliary winding all in series. This auxiliary winding produces a magnetic field which opposes and neutralizes, the reaction of the armature. It is so formed that it need not be disturbed in order to remove the main field coils.

The armature core is built up of soft steel punchings which are assembled on a cast iron spider, and held in place and keyed to prevent their turning. The surface

is slotted, and the armature winding is arranged in three layers. The two upper layers are composed of copper strap connected to form the usual direct-current type of winding. The third layer constitutes the preventive winding. It is connected between the commutator and the main winding. This preventive winding is so proportioned as to prevent sparking, due to the normal working current, and that which is produced in the coil under commutation, when short-circuited by the brush in an alternating field. The individual coils are insulated along

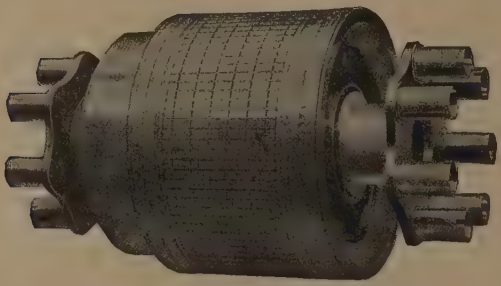


Fig. 188. Armature Mounted on Quills.

their entire length by overlapping layers of mica tape, and each group is further insulated from the core by a molded mica cell. The completed winding is held firmly in position by insulating wedges. The ends are banded down against the coil supports.

Suspension. The weight of each motor is carried on a frame which passes over the wheels and side frames, and rests on the journal boxes. Each frame carries four bolts which receive the weight of the motor, and each bolt is fitted with a heavy coil spring at its lower end through

which all weight is transmitted to it, so that the motor is carried on very flexible springs, and is independent of the truck frame. The torque of the motor, and the jar caused by sudden starts and stops, are transmitted from the motor to the truck through heavy tie-rods which affect the motion of the motor only lengthwise of the locomotive. The armature is not placed directly on a shaft but is built up on a quill through which the car axle passes with about five-eighths inch clearance all around. The

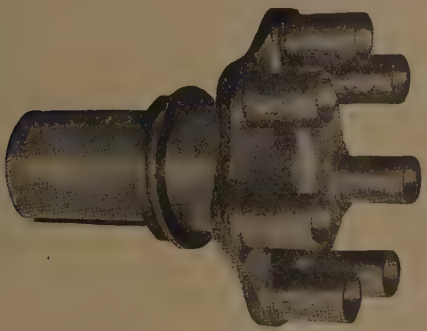


Fig. 189. Driving Quill.

bearings which carry the field frame are mounted on this quill, and from a flange at each end of the quill seven round pins project parallel to the shaft into corresponding pockets formed in the hub of the driving wheel. The torque of the motor is transmitted from these pins to the wheel through helical steel springs, which are wound with their turns progressively eccentric, and which are contained between two steel bushings, the smaller of which slips over the pin and the larger fits in the pocket in the wheel. These springs are under compression both longi-

tudinally, and horizontally so that, at all times, they fill the pockets in the wheel, but permit a vertical and a lateral motion. Their longitudinal compression between the quill, and the segmental cover over the outer ends of the pockets in the wheel keeps the motor at all times midway between the hubs. The end play of the motor

Fig. 190. Pockets in Driver for Fingers of the Quill.

does not come directly on the wheels, but is taken by strong coiled springs inside of the driving pins, which press against the covers in the outer ends of the spring pockets in the wheels. Though normally required to transmit only the torque of the motor, and to keep the motor axis parallel to the axle, these springs are amply strong to carry the entire weight of the motor. They

allow a total vertical movement of about ¾ inch. The torque of the motor is taken by heavy parallel rods, which anchor the frame to the truck above, and below the axle, and permit vertical or side motion of the motor, but prevent excessive bumping strains from coming on the driving springs. If these springs are compressed more

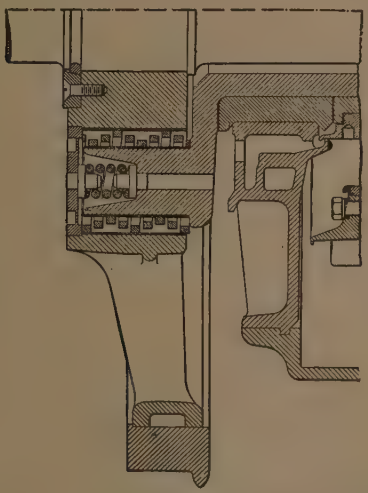


Fig. 191. Method of Placing Springs Between Quill Fingers and Driving Pockets.

than ¼ inch by the heavy centrifugal force exerted by the motor when rounding curves, the force is taken up by noses on the motor which fit into corresponding recesses in the cross ties between the side frames of the locomotive.

This suspension has the advantage of removing all dead weight from the axle, of driving through springs, and at the same time of having the motor thoroughly anchored to prevent undue strain on the driving spring. The only parts of the locomotive not spring supported are the driving wheels, axles and journal boxes.

Forced Ventilation. The motors are arranged for ventilation, by a forced circulation of air which enters under pressure, is distributed throughout the motor, and escapes through the perforated covers. In the floor of the cab there is a natural conduit formed by the side channels of the frame, the floor and side walls of the cab, and a lower plate, through which air is carried to the motors, transformers and resistances. This method of cooling improves the continuous capacity of the apparatus and is, in a large measure, accountable for the high continuous rating of the motors which almost equals that on the one-hour railway basis. The air furnished to the motor may be taken from the inside of the cab, and can therefore be kept relatively clean and dry.

Current Collection. On the direct-current part of the line, current is taken from the third-rail system by eight collecting shoes, four on each side of the locomotive, arranged in pairs of two each. There are two pairs on each side, one at each end, for the purpose of bridging such gaps as may occur in the third-rail system. The direct-current contact shoes are designed to work on two forms of third rail—one in which the shoe runs under the rail, and the other on top of the rail. To collect alternating current from the high-potential overhead trolley line, the locomotive is equipped with two pantagraph type, bow trolleys, each of which has a capacity sufficient to carry the total current required by the locomotive un-

der average conditions—two being provided to insure reserve capacity.

The Control System. On direct current the motors are controlled in series parallel as in ordinary railway practice. In alternating current operation no resistance is used in the regular run, but a small resistance, which constitutes a preventive device to diminish the short-circuiting effect when changing from one transformer tap to another, is employed in passing from one working step to the next. There are six alternating-current voltages

Fig. 192. Master Controller.

or running points, corresponding to six taps from the auto-transformers, and there are a small number of midway steps, which are used only in passing between working notches. Experience has shown that the number of steps required in alternating-current operation to give a smooth acceleration is considerably lower than in direct-current practice. In consequence, the controller is so arranged that on alternating current about half as many steps are used as on direct current. Tests so far conducted show that the acceleration on both alternating, and direct current is very smooth.

There is one feature of the direct-current control which is not generally found at the present time in direct-current equipments, viz., the shunting of the field for higher speeds. In the series position in direct-current operation, the motors have an efficient running point. It is usual railway practice to pass from the series, to the multiple position without an efficient intermediate running speed. With the New Haven equipments, however, the type of motor used permits shunting of the field without impairment of commutation, or operation, and higher speeds are provided by shunting the fields before passing into multiple. In this way several efficient running points are obtained between the series and multiple positions; and tests have shown that these motors operate properly on direct current with their fields shunted down to half their normal strength. When operated on direct current, the current is fed directly to the motors. On alternating current, however, auto-transformers are required, as the alternating-current trolley voltage is 11,000. Two such transformers form part of each equipment; one mounted on each side of the cab floor to balance the weight. They are connected in parallel across the high voltage, but on the low-voltage side each transformer feeds one pair of motors through a separate control unit. This means that the control system, when operated on alternating current, consists of two normally independent units.

The main controllers are the Westinghouse electro-pneumatic unit switch type. The design differs somewhat from that used in direct-current service, because of the fact that the switches, blow-outs, etc., must operate on both alternating, and direct current, as many parts of the controller are common to both systems. The reversing switches are also parts of the unit switch groups. The

main controllers are operated from master controllers at each end of the cab. The control system is arranged for multiple unit service, so that two or more locomotives can be coupled to the same train and handled by a single driver.

There are six switch groups, each containing unit switches. The two line switches are so connected in the switch groups that each carries the current supply to each pair of motors when they are operating in parallel combination. When the motors are in series, one of the line

Fig. 193. Unit Switch Group.

switches carries the current supply to all. Each line switch is provided with an overhead trip, so connected that all of the switches of both switch groups, as well as both the line switches open in case of an overload, or short circuit on either pair of motors or in the circuit of either pair. The overload trip is automatically locked out when brought into action, and cannot be reset until the master controller is returned to the off position.

The external resistances used in regulating the flow of current to the motors are arranged in two groups which are connected in series when the motors are in series, and

in series with each motor when the motors are in parallel. The change over between the direct current third rail, and the alternating current overhead system can be made easily and quickly, even when the locomotive is running at full speed.

An ammeter is mounted in each end of the locomotive, in plain view of the operator, when at the master controller.

The master controller is of the drum type, and is operated by a lever which moves through an arc of about 60 degrees, with notches and latch wheel to define the different positions. Reversing is accomplished by a separate handle, which interlocks with the main lever. When the master controller is in the off position, connections are so established that all circuit breaker trips which may be open are closed by the simple closing of a small switch conveniently located in the locomotive cab. Current is supplied to the control circuits by two sets of 7-cell storage batteries, each of which has a capacity of 40 ampere-hours and weighs 150 pounds.

In connection with the switch groups, cut-out switches are provided so that either pair of motors may be cut out by simply rendering certain switches inoperative. It is thus possible to cut out the motors without manipulating the main circuit.

Auxiliaries. The auxiliary equipment includes two air compressors driven by motors, which can be operated on either alternating, or direct current; two blowers driven by similar motors, and which furnish air to the transformers, motors and direct-current rheostats; oil circuit-breakers for the high-tension circuits; switches to change the equipment from alternating to direct current; a steam generator to supply heat to the railway coaches in cold

weather; a complete Westinghouse air brake equipment, signal apparatus, automatic bell ringers, whistles, sanding apparatus, etc.

Dimensions and Performance. The New Haven locomotive measures 36 feet, 4 inches over the bumpers, and weighs approximately 85 tons. It is capable of handling a 200-ton train in local service on a schedule speed of 26 miles an hour, with stops averaging about two miles apart —making in such service, a maximum speed of about 45 miles per hour. It can also handle a 250-ton train on through service with a maximum speed of about 60 miles an hour. With heavier trains it is planned to couple two or more locomotives together, and operate them in multiple.

Tests. The tests which have been made on the first locomotive equipped show that it will, without difficulty, meet all the requirements for which it has been designed.

This locomotive has, on actual test, repeatedly accelerated a 200-ton train at a rate of .5 of a mile per hour per second, which is in excess of the rate required by the service conditions of the New Haven road. The locomotive has been operated at speeds above 60 miles per hour without difficulty.

In Fig. 182 is shown a locomotive standing in D. C. zone with both trolleys and shoes down; when standing in A. C. zone, as in Fig. 183, both trolleys and shoes are up. In Fig. 184 is shown a regular New Haven train.

One of the two trucks under the locomotive is shown in Fig. 185. One complete motor mounted on its pair of drivers is shown in Fig. 186. The eyes for the tie rods, three on each side show plainly. On a level with axle are two lugs on each side, through which the four suspension bolts pass.

The complete armature with the end plates which support field, are shown in Fig. 187, mounted on the axle. Fig. 188 shows armature with its driving quills. Fig. 189 shows one driving quill in greater detail. Note the central hole through which locomotive axle passes. The key way to connect armature spider to quill is shown. The driving pegs of quill are hollow to contain the end thrust springs.

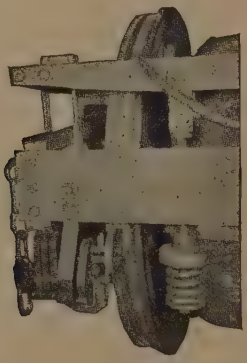


Fig. 194. Speed Recorder.

Fig. 190 shows the outside of driver with the driving pegs in the pockets of driver. Two of these pockets have the cover plates in position. Fig. 191 gives the details of the springs.

Fig. 192 shows the master controller, and Fig. 193 a group of unit switches.

Each locomotive has a speed indicator whose mechanism is shown in Fig. 194. It being a magneto, frictionally driven from a locomotive driver.

ELECTRICALLY OPERATED TURN TABLES.

In the yards of all our large railroads the hand operated turn table has gone out of use, or ought to go at once.

Locomotives are so heavy, some weighing 175 tons and a few even 200 tons, that it requires too many men to turn, especially in winter.

In busy junctions and terminals, the hand turning, being so slow, is a great source of congestion and delay.

A steam "donkey" or single wheeled locomotive is occasionally used to turn the table, being attached to one end and running on the same rails as the wheels of the turn table.

The equipment consists of a small vertical boiler, a steam engine, a water tank and a coal bin. Water and coal must be brought to the table, and ashes taken away. In many places a licensed engineer is required by law. If some old locomotive engineer has the job, it is wasting a valuable man on a poor job, as his knowledge of railroading, and the road should be utilized where they will be of service.

It has often been suggested that a pipe be run from the station heating plant, or the shop boilers. Steam from this pipe, which should run underground to the center of the table pit, would be taken through a pivoted slip joint to the "donkey."

In this case, owing to the length of pipe, the engine would have to run on hot water most of the time.

The electric motor is just the thing to operate a turn table, and it is rapidly coming into general use.

Fig. 195. Turn Table with Donkey.

Where a terminal has been electrified, the electric turn table goes without saying, but it will pay any road to install an electric turn table even if they must buy power from the local electric light company.

The same dynamos which furnish 125 or 250 volts for lighting the station, or shops can operate the turn table motor.

The regular equipment would be a small railroad motor, with the ordinary gearing, a rheostatic controller and a circuit breaker, the whole being mounted on a single wheeled truck. This constitutes an electrical "donkey." Such a turn table is shown in Fig. 195.

Where a large number of engines must be handled quickly, a regular turn table operator should be employed, and a cab built over the "donkey" for his protection.

There are many cases, however, where it is feasible for the locomotive fireman to operate the turn table. In such a case the controller should be installed in the middle of the table at one side, and the cab is not essential.

The details of the "donkey" are well shown in Fig. 196, while Figs. 197, 198 and 199 give all the information of the equipment that would be required. Note that the rails can be sanded in both directions.

The cost of a turn table "donkey" as in Fig. 195 is about $1,000.

Single wheel truck	$ 350
Electrical equipment	500
Installation	150
	$1,000

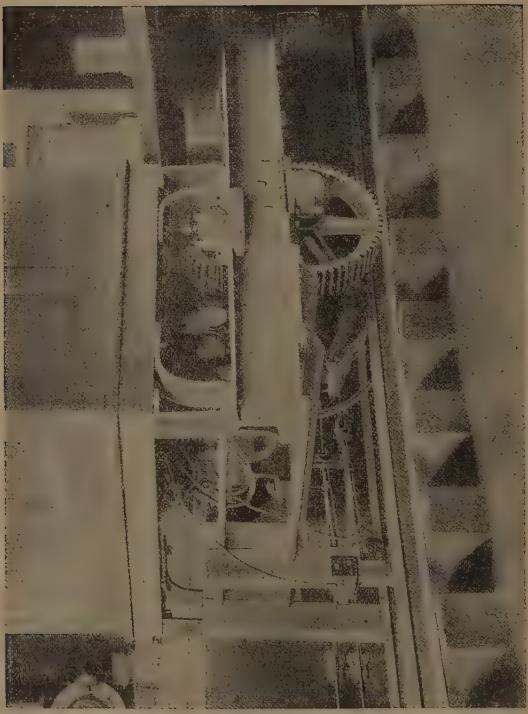


Fig. 196. Under Part of Donkey.

This is based on the assumption that the railroad shall buy the truck from a truck builder, have the mechanical work done in their own shops, and let the electricians install the electrical equipment when received from the manufacturers.

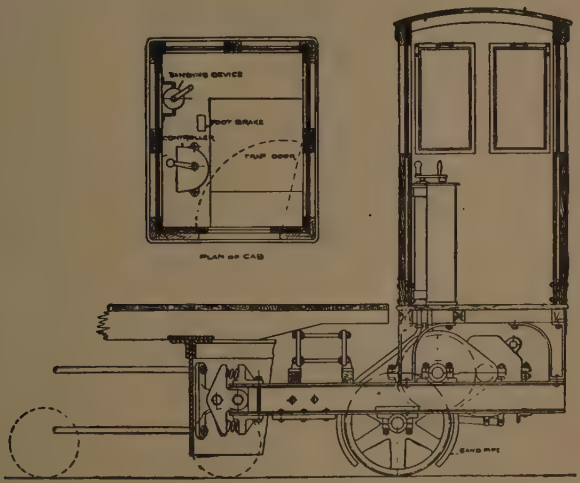


Fig. 197. Side View of Donkey and Plan of Interior of Cab.

The turn table shown in Fig. 200 is of the "draw bridge" type. The table rests on a heavy cradle which turns on a train of small wheels.

A large stationary gear as shown, is engaged by the pinion of the vertical motor shaft.

It should be noted that a "donkey" drives by friction like a locomotive, so that ice on rails, or oil will reduce

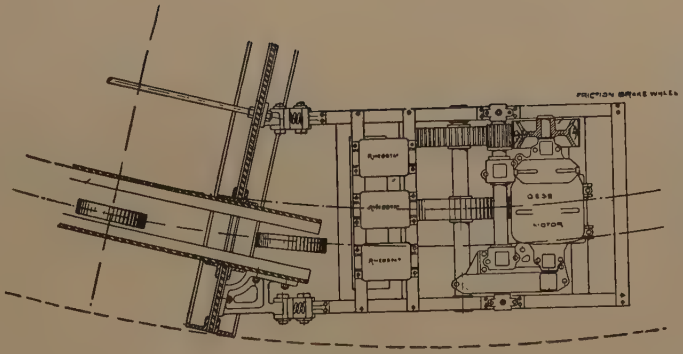


Fig. 198. Plan of Under Part of Donkey.

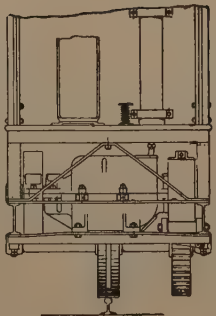


Fig. 199. End View of Under Part of Donkey, Gear Wheel of Motor on Right, Single Drive Wheel in Center.

traction and make sand necessary. The "draw bridge" type drives positively by a gear.

Whatever type is used, the ordinary street railway motor is best adapted to the purpose. It is completely enclosed and water and dust proof.

The conditions of frequent starting, and large momentary overloads, make the direct current series motor the best. If only alternating current is obtainable the compensated series motor will give good service. If only multiphase alternating current can be obtained, an induction motor will do the work better than hand or steam. The induction motor should be of the definite wound armature, collector ring, external resistance type, and be designed for speed variation.

In any case the motor must be designed, and constructed to stand rough use and even positive abuse.

The motor is usually provided with feet, and in place of the car axle, an intermediate shaft is substituted so that there is a double reduction gearing. Both sets of gears run in a gear case filled with oil or soft grease.

The armature shaft of motor is extended at the end opposite the pinion, and a hand brake fitted. Sometimes this is set by a wheel and sometimes by a weight or a spring and is released by a foot lever.

The controller is like a street car controller, except that it has no separate reverse wrench.

The handle being in center, power is off; moving it to right turns table to right, to the left turns table to left.

The resistances are like those on a street car.

The circuit breaker serves as a switch, and protects from serious overloads.

The advantages of electrically operated tables are: Low cost of maintenance and operation; speeds up,

Fig. 200. Draw Bridge Type of Turn Table.

moves and stops quickly; perfect control of speed; consumes power only when work is done.

Perhaps time saving is its greatest advantage. In a certain terminal the new round house was built to accommodate twice as many locomotives as the old one. The electrical turn table served this round house with less delays than the hand table caused when serving the old house.

The actual power required to turn a 60-foot table with a 100-ton engine on, is from 8 to 12 H. P. The speed of operation was one turn in 40 seconds. At the moment of starting the power ran up to about 20 H. P.

It is for this reason that a 20 H. P. railway motor is installed.

A 10 H. P. motor of regular type would operate the table, but not as well. The reason is not because the 20 H. P. railway motor is more powerful than a 10 H. P. regular motor, for strange to say they are of about equal power.

The railway motor is best suited to the work, and should be installed.

No time should be wasted in trying to balance engines on the table; in fact, the 8 H. P. result was obtained with engine slightly out of balance; 9 H. P. was, when engine was balanced, and 12 H. P. when much out of balance.

In one yard where the electric table turned 30 locomotives a day, the cost of the power used was less than the cost of hauling the coal to the steam donkey previously employed. It would have been utterly foolish to waste time in balancing engines to try to save a little power.

In this yard the actual cost of turning a locomotive

by electric power from their own shop, was 1.4 cents. This was obtained by averaging the total expense for six months' use of the table. Had this power been purchased from the local electric light company, it would have cost them 1.9 cents per locomotive.

There are three good ways of bringing the power into the turn table:

The best way is to lead the wires from underground, up to a pair of cast iron rings, and have brushes in the table to collect the current.

When center pivots are solid, and the under bracing complicated this cannot be done.

For a turn table of this description the method shown in Fig. 196 is good.

Two trolley wires, in spans of 6 or 8 feet, are placed around the wall of the pit, supported by trolley hangers of the "toggle" type, ordinarily used in electric mine haulage. Short trolley poles are flexibly attached to the "donkey," so as to allow a horizontal movement on account of the variation in the trolley wires, and a vertical movement to accommodate the tilting of the table. This scheme is simple and inexpensive, and in practice has operated in a very satisfactory manner.

In some places, on account of the possibility of the pit being flooded, neither of the arrangements described above is practicable, and it becomes necessary to collect the current from above the turn table. A very ingenious arrangement for this purpose has been used on a turn table where the pit occasionally fills with sea water. A light arch was built over the center of table to support directly over pivoted point the device shown in Fig. 201. The case is a piece of 8-inch steam pipe with a regular

cap fitting screwed on each end. A bearing is set in at the top and a stuffing box at the bottom.

The case is held stationary by wire rope guys attached

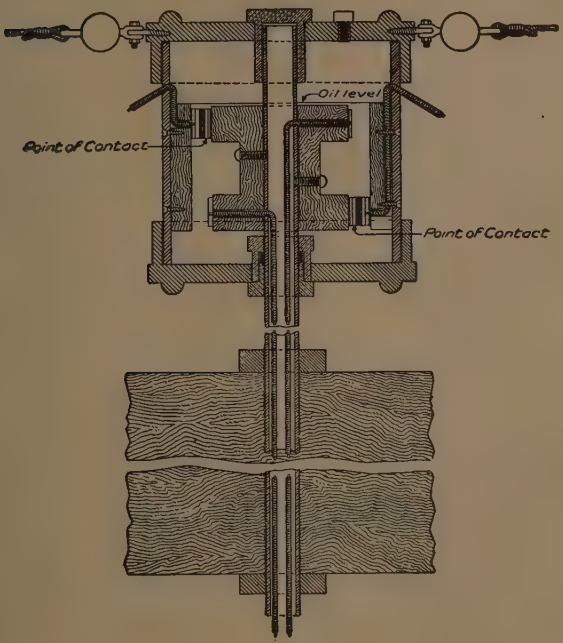


Fig. 201. Overhead Contact for Turn Table.

to regular trolley road insulators, and the two electric wires enter the case and end in copper brushes insulated by a hard wood shell.

A piece of 1-inch gas pipe turned smooth on the outside, at one end is fastened to the table. Its upper end revolves in the bearing of the case, and takes most of the weight of it. The guys merely steady it, and prevent rotation. The gas pipe revolves in the oil tight stuffing box at bottom of case. A hard wood spool on the gas pipe carries two copper rings which collect current, and from which the two wires run down inside the pipe to the turn table.

The case is filled with oil which serves a triple purpose; it lubricates, insulates, and prevents the gases and steam from the locomotive from ruining contacts and insulation.

OPERATION OF LOCOMOTIVES.

CATECHISM.

In order to be able to designate the position of the different pieces of apparatus in the cab the ends are called Nos. 1 and 2, while the sides are named right and left.

The hand brake wheel and the storage batteries are in the No. 1 end and on the right hand side. The other end is the No. 2 and the other side is called left side.

If you stand at the controller in No. 1 end, the side of locomotive on your right is the right side.

The motor in No. 1 end of locomotive is motor No. 1 and the others are numbered Nos. 2, 3 and 4.

All the apparatus for No. 1 truck is on the left side of locomotive, and the apparatus for No. 2 truck is on right side of locomotive.

The reverse lever can be removed from controller in the "off" position. In forward and reverse positions it is locked in.

The controller plug is attached to the lever with a chain.

Until the controller plug is in place and the reverse lever in forward or reverse position no current can flow through the controller contacts.

The controller lever is part of the controller and not removable.

STANDING IN A. C. ZONE.

Question 1. In what position should the apparatus be placed when locomotive is lying idle in an A. C. terminal or standing in A. C. zone not coupled to a train?

Answer. The apparatus should be arranged thus:

1. Both A. C. trolleys locked down.
2. Both A. C. circuit breakers open.
3. Both compressor switches open.
4. Both blower switches open.
5. Controller lever in off notch.
6. Reverse lever and controller plug removed.
7. Both battery switches open.
8. Motor-generator knife and snap switches open.
9. Third rail shoes up.
10. D. C. main switch handle in down position.
11. Heater circuit switches (double throw) in down position.
12. Train line heater switch open.

Question 2. What is the reason for this arrangement of apparatus?

Answer. So that all communication with outside power is cut off, and all apparatus left in the safest possible condition.

Question 3. If locomotive is blocked on road, kept standing under orders, or is standing coupled to a train, how should apparatus be arranged?

Answer. For first 30 minutes leave apparatus in normal running positions.

Then read temperature meter. Should it read below 50 degrees:

1. Shut off fan motors.
2. Open both battery switches.

3. Open both motor-generator switches.
4. Open both A. C. circuit breakers.

Should temperature be above 50 degrees wait until it falls to 50 degrees and then proceed as above.

STANDING IN D. C. ZONE.

Question 4. What should be the position of apparatus when locomotive is lying idle in a D. C. terminal or standing in a D. C. zone not coupled to a train?

Answer. The apparatus should be arranged thus:

1. Both A. C. trolleys locked down.
2. Both A. C. circuit breakers open.
3. Both air compressor switches open.
4. Both blower switches open.
5. Controller lever in off notch.
6. Reverse lever and controller plug removed.
7. Both battery switches open.
8. Both motor-generator switches open.
9. Third rail shoes down.
10. D. C. main switch down.
11. Heater circuit switches (double throw) down.
12. Train line heater switch open.

Question 5. What positions should apparatus occupy when blocked, held under orders, or standing coupled to a train in a D. C. zone?

Answer. Leave everything in normal running position until 30 minutes elapse. Then watch temperature meter. When it falls below 50°:

1. Shut off fan motors.
2. Open battery switches.

PREPARATION FOR RUN.

Question 6. What should be done in preparing for a run?

Answer. Prepare for a run thus:

1. Both batteries should be tested by using the 20-volt lamp provided for this purpose. Lamp should burn at full brilliancy.
2. Inspect the A. C. trolley locks to see that they operate properly.
3. Raise and lower the D. C. trolley.
4. Lower the third rail shoes. If in D. C. zone they should stay down, while in A. C. zone they should automatically return to the up position.
5. Before the first run each day, fill central groove of each A. C. trolley with heavy grease.
6. See that sand boxes are filled.
7. Test bell, sander, and lighting circuits.
8. Test out the control (as described later).

Question 7. Should A. C. trolleys be used alternately?

Answer. Yes. Change trolleys each day. Under no circumstances use one trolley continuously. At end of each day's run cut out the trolley used that day and cut in other trolley ready for next day's run.

Question 8. How is the trolley cut out?

Answer. After locking down, the lock is cut out by closing the air cock on the trolley side of the magnet valve leading to the unlocking cylinder of this trolley.

Question 9. What should be done in making ready to start?

Answer. In A. C. zone:

1. See that both A. C. circuit breakers are open.
2. See that safety chains are not fastened to trolleys.

3. Raise the A. C. trolley, whose lock is not cut out, by pushing down the controller button marked "Shoe and Trolley Unlock," or this failing, by methods described later.

4. Close both A. C. circuit breakers.

5. Start air compressors and pump up 140 pounds pressure in reservoir. Compressor should automatically cut off at that pressure.

6. Throw battery switches up on the even days of the month and down on the odd days.

7. Start motor-generator by closing the snap switch first, and then the knife switch.

8. Insert the controller plug and reverse lever.

9. Start fan motors. Fans must be kept in constant operation while the locomotive is running.

In D. C. zone:

1. Start air compressors and see that 140 pounds pressure is attained in reservoir, and that compressors automatically cut off at that pressure.

2. Throw battery switches up on the even days of the month, and down on the odd days.

3. See that motor-generator switches are open.

4. Insert controller plug and reverse lever.

5. Start fan motors. Fan motors must be kept in constant operation while the locomotive is running.

AT END OF RUN.

Question 10. What must be done at end of a run?

Answer. The apparatus must be arranged in the same positions as for standing in a zone.

The reverse lever and controller plug must be handed to proper official.

OPERATION OF LOCOMOTIVES.

Question 11. How should a train be handled while leaving a terminal?

Answer. In leaving a terminal, in passing over switches, cross-overs or turn-tables, in coupling up to trains, and at other places where a slow speed is required, the controller lever should be placed in one of the switching positions.

Question 12. Should lever be kept in a switching position?

Answer. No. The A. C. switching position is wasteful of power, and must not be used as a running position. Use no longer than is absolutely necessary.

The D. C. switching position is not only wasteful, but operation of the locomotive with lever in this position for too long may result in burning out a resistance grid.

Question 13. How should a low speed be maintained in D. C. zone?

Answer. By bringing lever to D. C. Series; retain lever in this position for a short time, shut off and coast. In this way a very low average speed may be maintained.

Question 14. What is the off position of controller lever?

Answer. The first three notches on the controller are not numbered. When lever is in first of these it is in off position and all unit switches are open.

Question 15. What are the running positions of controller lever in A. C. zone?

Answer. The notches 6, 7, 8, 9, 10 and 11 are the A. C. running positions.

Question 16. What is the A. C. switching position?

Answer. Notch 3 is the A. C. switching position.

Question 17. What are the running positions of lever in D. C. zone?

Answer. Notches 10, 11, 12 and 20 are D. C. running positions.

Question 18. What is the D. C. switching position?

Answer. Notch 1 is the D. C. switching position.

Question 19. What are notches 2, 4, 5, 13, 14, 15, 16, 17, 18, 19 which have not been mentioned?

Answer. These are notches where changes in the connections of the circuits are made, but where the combinations are not suitable, or are unsafe for continuous use.

Question 20. Should controller lever be held on one of these notches?

Answer. No. These notches should be passed over quickly.

Question 21. In giving the A. C. positions of controller lever, notches 1, 2, 4, 5 and 12 to 20 inclusive were not mentioned. Why?

Answer. When operating in A. C. zone the notches from Off to 2 inclusive, and from 12 to 20 inclusive are dead.

The controller lever at any one of these notches makes no electrical connections.

Notches 4 and 5 give such a low voltage to the motors that they waste power, and so are not used.

Question 22. When giving D. C. positions of controller lever notches 2, 4, 5 and 13 to 19 inclusive were not spoken of. Why?

Answer. Because these notches are positions where connections are made which are unsuitable, or unsafe for continuous use.

Question 23. How is train operated in A. C. zone?

Answer. To start train, controller lever should be drawn from Off to A. C. No. 1 with a single motion. The lever may then be drawn to A. C. Nos. 2, 3, 4, 5 and 6 (in the same manner), as fast as is required to obtain the desired acceleration.

Question 24. What precautions must be taken to prevent too much power being used?

Answer. While the locomotive is accelerating the ammeter should be watched carefully. A current of 1,600 amperes should be maintained as nearly as possible. More than 1,800 amperes must not be drawn.

Question 25. Suppose the controller lever is pulled beyond A. C. No. 6?

Answer. If the lever is pulled beyond A. C. No. 6 the power will be cut off, and locomotive will be coasting.

Question 26. May controller lever be pushed back to A. C. No. 6?

Answer. If speed of locomotive has not been reduced much, push lever back to A. C. No. 6.

Should speed be considerably reduced, pull the controller plug out, push lever back to Off position, replace plug, and pull lever to desired running position.

Question 27. How should train be operated in D. C. zone?

Answer. In starting a train with D. C. power the controller lever should be brought to a notch which will give a current of 1,600 amperes on the ammeter. After a few seconds' pause bring lever to D. C. series position.

Question 28. What precautions must be taken to prevent too much power being drawn during acceleration of train?

Answer. While increasing speed watch the ammeter. Never exceed 1,800 amperes.

Should 2,500 amperes be drawn, fuses will blow.

Question 29. What is to be done if ammeter reads over 1,800 amperes?

Answer. Wait until current drops to 1,600 amperes before moving controller lever to next position.

Question 30. How may speed be increased beyond D. C. series?

Answer. The lever should be placed in the D. C. shunt No. 1 position, or D. C. shunt No. 2 position.

If a still higher speed is desired move with a single motion to D. C. full multiple.

To run very slowly alternately coast, and run on D. C. series.

Should endeavor to run on any position result in a steady indication of over 1,800 amperes the train is too heavy, brakes are not released or trouble has occurred. Investigate at once.

CHANGE FROM A. C. TO D. C. OPERATION.

Question 31. How is the change-over point from A. C. to D. C. marked?

Answer. There are two sign-posts on the right-of-way. The first is marked "Shoes Down" and the second marked "Power Off."

Question 32. How is the change-over made?

Answer. 1. On reaching the sign "Shoes Down," press the controller button marked "Shoes Down" and see that the shoes on both sides go down.

2. When sign "Power Off" is reached throw controller lever to Off position.

3. Open storage battery knife switch, and then motor-generator snap switch.

Question 33. What changes take place in arrangement of other apparatus?

Answer. As soon as the shoes come in contact with the third rail the A. C. trolley is automatically lowered; the change over switches cut out A. C. apparatus and cut in D. C. apparatus.

Question 34. How is locomotive operated immediately after passing change-over point?

Answer. When it is seen that D. C. power has entered locomotive, and the A. C. trolley is down, pull controller lever to the position which gives desired speed.

CHANGE FROM D. C. TO A. C. OPERATION.

Question 35. How is change-over point from D. C. to A. C. marked?

Answer. There is a sign-post on the right-of-way marked "Controller Off."

Question 36. How is change-over made?

Answer. 1. Immediately on reaching the sign throw controller lever to Off position.

2. Press the controller button marked "Shoe and Trolley Unlock" and hold this button down until the shoes leave the third rail.

3. Close motor-generator snap switch, and then storage battery knife switch.

Question 37. What changes occur in arrangement of apparatus?

Answer. The shoes automatically fold up to the side of the locomotive and the A. C. trolley is automatically forced up against the trolley wire.

The change-over switch cuts out D. C. apparatus and cuts in A. C. apparatus.

Question 38. How is locomotive operated immediately after passing change-over point?

Answer. As soon as A. C. power enters locomotive and these changes have occurred, pull controller lever to such a position as will give the desired speed.

Question 39. Why is it of the utmost importance to throw controller lever to Off at the sign-post in both change-overs?

Answer. Because if the locomotive is drawing current at the moment shoes leave the third rail a vicious arc will be drawn which will damage the shoes.

In a like manner an arc would be formed between trolley and trolley wire when contact was broken. The current being small the arcing is very much less than the arcing at the shoes.

OPERATION ON D. C. OVERHEAD RAIL.

Question 40. Where will D. C. overhead rail be encountered?

Answer. In the D. C. zone at cross-overs and switches or any place where there is a gap in the third rail, the gap is spanned by an overhead rail.

Question 41. Is this rail always used?

Answer. No. An endeavor should be made to coast all these gaps. With long gaps, or heavy trains, power must be obtained from the overhead rail.

Question 42. How is power obtained from overhead rail?

Answer. Power is obtained from overhead rail by holding down the controller button marked "D. C. Trolley Up" as long as it is desired to obtain power.

Question 43. How should locomotive be operated while power is drawn from overhead rail?

Answer. Should speed of train have been reduced before trolley is raised it is best to throw controller to Off position and then pull up to desired notch.

Ordinarily the position of controller lever may remain unchanged.

OPERATION ON A. C. THIRD RAIL.

Question 44. Where will A. C. third rail be encountered?

Answer. All long draw bridges are equipped with A. C. third rail.

Question 45. Is this rail to be used in normal operation?

Answer. No. The draws are to be coasted with the A. C. trolley down.

Question 46. Describe method of coasting a draw bridge.

Answer. When approaching the draw watch for the end of the overhead trolley wire. Just before the end of trolley wire, throw controller lever to Off position, and press on controller button marked "A. C. Trolley Down."

After draw has been passed, press down button marked "Shoes and Trolley Unlock."

The A. C. trolley will rise into contact with trolley wire, and controller lever may be pulled to desired position.

Question 47. What is proper procedure if stalled on a draw bridge?

Answer. 1. See that the double throw heater switches are both in the up position.

2. Throw the D. C. main switch to the upper position.

3. Lower third rail shoes by pressing the controller button marked "Shoes Down."

4. Signal tower operator to cut current into the third rail.

5. Start the train very slowly, and run at slow speed, as drawing a heavy current is quite likely to damage apparatus.

6. Throw controller lever to Off just before reaching end of third rail.

7. Throw D. C. main switch to the down position.

8. Raise trolley by pressing controller button marked "Shoes and Trolley Unlock," which will also fold up shoes.

DOUBLE HEADING.

Question 48. How should locomotives be arranged for double heading?

Answer. 1. Make the three jumper connections between locomotives.

2. Test control of each locomotive. Each must be perfect.

3. Remove the controller plug and the reverse lever from all controllers, except the one from which train is to be operated.

4. Raise one trolley on each locomotive.

Question 49. Is there any difference in handling double headed trains?

Answer. No. Except that in case of trouble pull jumpers between locomotives before investigating.

RAISING A. C. TROLLEY.

Question 50. How is A. C. trolley raised in normal operation?

Answer. Under normal conditions the A. C. trolley may be raised by pressing controller button marked "Shoes and Trolley Unlock" which causes air from main reservoirs at 130 pounds pressure to operate the unlocking cylinders.

Question 51. Suppose after standing for some time the pressure has leaked off from these reservoirs?

Answer. If there is sufficient pressure in the emergency control reservoir, (which normally carries 130 pounds pressure) it may be used to unlock trolleys thus:

Throw to the right the handle of the three-way cock directly above the reservoir.

After the trolley has unlocked, return handle of three-way cock to its normal position.

Question 52. Suppose emergency control reservoir pressure has also leaked off?

Answer. In this event trolley No. 2 may be unlocked by the hand pump.

To do this:

Close the cock in the air pipe connecting this trolley lock with its magnet valve.

Open cock connecting trolley lock with pump.

Three or four strokes of pump should unlock trolley.

After trolley is up, close connection to pump, and open connection to magnet valve.

Question 53. Should all these fail to raise trolley what should be done?

Answer. The latch of the trolley lock may be pulled

by the hook on the end of the wooden pole carried on the locomotive for this special purpose.

Question 54. What precautions should be observed in unlatching trolley?

Answer. *Never go on top of the locomotive to unlatch trolley,* as it can be done from the ladder or while standing in the side door.

Keep pole dry when not in use, and in wet weather use rubber gloves.

RAISING D. C. TROLLEY.

Question 55. How is D. C. trolley raised?

Answer. The D. C. trolley is raised by pressing controller button marked "D. C. Trolley Up" and holding it. As soon as button is released D. C. trolley is lowered. There is no hand pump attachment.

TESTING CONTROL.

Question 56. How is control tested in A. C. zone in daylight?

Answer. 1. See that there is at least 70 pounds pressure in the control reservoir.

2. Open A. C. circuit breakers.

3. Insert the reverse lever and throw to its forward position.

4. Notch up the controller to each successive A. C. position, and make sure that the proper switches as shown in Table A close at each A. C. position.

5. Return controller handle to the Off position.

6. Throw reverse lever to backward position.

7. Repeat test as in 4.

8. Close A. C. circuit breaker.

Question 57. How is control tested in A. C. zone at night when electric lights are used to illuminate the cab?

Answer. The test can be made on half the equipment while electric lights are in use.

To test switch groups Nos. 4, 5 and 6, which are on right hand side of cab, proceed thus:

1. See that balancing transformer is completely disconnected, by throwing both the heater circuit switches to the down position.

2. Open both air compressor switches.

3. Disconnect No. 1 (right hand) auto-transformer from the trolley by opening right hand A. C. circuit breaker.

4. Throw handle of No. 2 motor control cut out, to the Out position.

5. Insert reverse lever and controller plug. Throw reverse lever of controller to forward position.

6. Notch up the controller lever to each successive A. C. position and see that the proper switches in switch groups Nos. 4, 5 and 6 close at each A. C. position.

7. Return the controller lever to the Off position.

8. Throw reverse lever to the backward position.

9. Repeat test as in 6.

10. Throw reverse lever to central position.

To test switch groups Nos. 1, 2 and 3 on the left hand side of locomotive proceed thus:

11. Throw the handle of the No. 1 motor control cut out, (on right hand side) to the Out position.

12. Reset the right hand hand A. C. circuit breaker.

13. Open the left hand A. C. circuit breaker.

14. Throw the handle of the No. 2 motor control cut out, (on left hand side) to the In position.

15. Throw reverse lever to forward position.

16. Test as in 5, the switches in switch groups Nos. 1, 2 and 3.

17. Return controller lever to the Off position.

18. Throw reverse lever to backward position.

19. Repeat test as in 16.

20. Reset the left hand A. C. circuit breaker.

21. Throw handle of left hand motor control, cut out (No. 1) to In position.

Testing in this manner leaves the lighting circuits connected to trolley throughout the whole test.

Question 58. How is control tested in D. C. zone?

Answer. 1. Open D. C. main switch.

2. Insert reverse lever and controller plug. Throw reverse lever to forward position.

3. Bring controller lever to each notch in succession, and note whether the proper switches close at each notch.

Test every notch from D. C. Switching. to D. C. Full Multiple.

4. Return controller lever to Off position.

5. Throw reverse lever to backward position.

6. Repeat test as in 4.

7. Close D. C. main switch.

Question 59. Do not the lights in the cab affect the test in a D. C. zone?

Answer. No. Opening D. C. main switch does not cut current off from lighting circuits; in fact it does not cut current off from lighting, heating, compressor or fan circuits.

TRAIN FAILURES.

FIRE.

Question 60. What is to be done in case of smoke or fire?

Answer. If an irregularity of operation exists, such as a short circuit, arcing, blowing of a fuse, smoke or fire, etc., immediately throw the controller to the Off position.

If in A. C. zone press the controller button marked "A. C. Trolley Down."

If in D. C. zone, insert paddles between third rail and all shoes.

Then investigate.

Question 61. How should a fire be extinguished?

Answer. By use of sand, or if fire is severe use the fire extinguishers provided in the cab of locomotive.

Question 62. Why should water never be used?

Answer. Water is a conductor of electricity. Should there be any current passing, the fire will be made worse by water. Even should there be no current passing wetting the apparatus will make it impossible to use them after fire is extinguished until taken apart and baked dry.

STARTING TRAINS.

Question 63. What current should be sufficient for starting trains?

Answer. A current of 1,800 amperes should be sufficient to start a train.

Question 64. If a train does not start readily at 1,800 amperes current what should be done?

Answer. Throw controller lever at once to Off position. Make sure that all brakes are properly released.

Question 65. If 1,800 amperes will not start train with brakes released what should be done?

Answer. The train is too heavy for one locomotive and should be double headed.

Question 66. Why should controller lever be so quickly thrown to Off position if train does not start?

Answer. Motors must not stand still an instant with current in them, else they will be burnt out.

Question 67. Why will current in an idle motor burn it out?

Answer. The transformer action of the A. C. current causes part of the armature to become a short circuited transformer with the result of a burn out.

TRANSFORMERS.

Question 68. What should be done when a transformer fails?

Answer. In case of trouble with a transformer, cut it out by opening the circuit breaker which feeds current to that transformer.

Disconnect the balancing transformer from the disabled transformer by throwing the double throw switch to the down position. Open the compressor motor switch belonging to the disabled transformer.

A. C. CIRCUIT BREAKERS.

Question 69. What current will make the A. C. circuit breakers go out?

Answer. A current of 1,800 amperes or over will cause one or both of the circuit breakers to go out.

Question 70. How are the A. C. circuit breakers reset?

Answer. The controller lever must always be in the Off position when a circuit breaker is to be reset.

To reset breaker: Press the button in the handle to unlock it, throw handle to its upper position where it will engage the operating lever, pull down and the circuit breaker will be reset.

Question 71. If circuit breakers go out repeatedly with less than 1,800 amperes what should be done?

Answer. The adjusting screw on the overload trip should be screwed down to a point where the circuit breaker will carry between 1,800 and 1,850 without operating the trip and causing circuit breaker to go out.

Question 72. Should adjustment of trip not stop the going out of circuit breaker, what should be done?

Answer. If the circuit breaker goes out repeatedly without apparent cause and adjustment of trip does not stop it, throw the motor control cut-out on the same side as the circuit breaker to the Out position.

This will cut out defective circuit breaker and also a pair of motors.

A. C. TROLLEY.

Question 73. What is to be done when there is any mechanical difficulty with A. C. trolley?

Answer. In case of trouble with a trolley, lower it by pressing controller button marked "A. C. Trolley Down."

Lock it down by closing the air cock on the trolley side of the magnet valve leading to the unlocking cylinder of this trolley.

Question 74. What is to be done if locking mechanism has been damaged?

Answer. The trolley should be tied down with a rope.

Question 75. Why not use the safety chains for fastening the trolley down?

Answer. The safety chains should never be used to tie down a damaged trolley, as these chains are grounded and will cause a short circuit.

Question 76. What is to be done if cable between two trolleys gives trouble?

Answer. Loosen set screws of the sockets in which this cable rests, and draw cable away from each trolley.

Use both trolleys to operate locomotive.

Question 77. Why is it that with trolley cable cut out both trolleys must be used?

Answer. Each trolley supplies current to one pair of motors. It is the trolley cable which enables one trolley to serve both pairs of motors.

Question 78. Suppose there is trouble in cable from trolley to circuit breaker?

Answer. When trouble develops in circuit breaker cable, disconnect it. This cuts out one pair of motors.

Question 79. What precautions are to be taken in disconnecting trolley cable?

Answer. Never go on top of the locomotive when any trolley is in contact with any wire.

When both trolleys are lowered and locked by closing air cocks, go on top and at once snap safety chains on both trolleys.

Closing the air cock prevents the raising of the trolleys by pressing controller button.

The safety chains prevent the trolleys being raised, even if the air cocks should be opened by some one and then controller button pressed.

The last thing before leaving top of locomotive unsnap *both* safety chains.

Should one trolley be raised while the safety chain was attached to the other, it would cause a short circuit

bad enough to open the line circuit breakers. This would cut power off line and delay other trains.

UNIT SWITCH GROUPS.

Question 80. To what causes can the failure of a switch group be traced?

Answer. Usually it is one of these three things; to be investigated in order named.

1. Low air pressure.
2. Low battery voltage.
3. Imperfect contacts in the control circuits.

Question 81. How should low air pressure be investigated and remedied?

Answer. Look at the control line pressure gauge and if it registers less than 70 pounds, while there is the normal pressure of 130 pounds in the main reservoir, look for trouble in the three-way cock or reducing valve.

Any slight obstruction in the three-way cock can usually be removed by throwing the handle from one extreme position to the other several times, and then returning it to its normal central position.

Any slight obstruction in the reducing valve, or its failure to work for any minor cause can be remedied by tapping it sharply several times with a hammer.

Question 82. How should low battery voltage be investigated and remedied?

Answer. Should movement of controller lever fail to operate the unit switches, throw both battery switches to the other position, thus cutting in a fresh battery.

Should this not cause switches to operate it may be that batteries are at correct voltage, and trouble is elsewhere.

Test both batteries with the 20-volt lamp; should it burn brightly, the batteries are all right, and fault is elsewhere.

Question 83. How should imperfect contacts be investigated and remedied?

Answer. If a movement of the controller lever to any running position results in the coneing in of a portion of the unit switches and a failure for the rest, the trouble is probably due to imperfect contacts of some of the fingers of the motor-control cutouts, change-over switches, or controllers.

To get train running as quickly as possible cut out the side of the locomotive in which the failure occurs and operate train with one pair of motors.

Should trouble affect both sides of locomotive proceed thus:

Arrange locomotive circuits as described for testing control, and notch up controller until point of failure is reached.

Open cases of the motor control cutouts, change-over switches and controllers.

Run a piece of wood along the control fingers and the interlocks pressing them into good contact. The response of the unit switches shows circuits to be perfect and locates the trouble in the contacts.

An adjustment of contacts can be made by bending the fingers.

Should trouble be found to be located in wiring on both sides of locomotive, call for assistance immediately.

THIRD RAIL SHOES.

Question 84. What should be done with a broken third rail shoe or shoe support?

Answer. With a broken third rail shoe or support:

1. Open D. C. main switch.
2. Open compressor switches.
3. Open blower switches.
4. Open train line heater switch. (The single pole single throw switch.)
5. Insert wooden paddles between the third rail and *all* shoes.
6. Break off or tie up the remainder of shoe or support, whichever will cause least delay.

Question 85. What precautions are to be observed when breaking off shoes, etc.

Answer. In breaking off shoes use a tool with a wooden handle such as a hammer or a sledge.

Never use a crow bar or coupler pin about an electric locomotive.

Never enter D. C. zone without at least one good shoe on each side of each truck.

CHANGE-OVER SWITCHES.

Question 86. How should trouble in change-over switches be investigated and remedied?

Answer. Failure may be due to low air pressure. See that at least 70 pounds pressure is in control reservoir, if not pump it up to normal 80 pounds pressure.

If this fails to operate change-over switch look for trouble in relay box.

Open relay box and see that the relays are in their proper positions:

In A. C. zone, both A. C. relays should be up and D. C. relay down.

In D. C. zone, both A. C. relays should be down and D. C. relay up.

If relays are not in their correct positions, do not attempt to repair them, but throw the change-over switch by hand. Report the trouble at terminal.

The handle of change-over switch should be down in A. C. zone and up in D. C. zone.

CONTROLLERS.

Question 87. How should trouble in controllers be investigated and remedied?

Answer. When poor contacts are made by controller fingers it can readily be detected and remedied.

If anything more serious seems to be the trouble, waste no time in investigation, cut out the defective controller. Take reverse lever and controller plug to other controller and operate train from it.

BRAKES.

Question 88. How should train be handled when air brakes fail?

Answer. The motors may be used as brakes as an extreme measure to prevent accident, ordinarily hand brakes are to be used.

Question 89. How are motors used as brakes?

Answer. 1. Throw controller lever to "Off."

2. Throw reverse lever to opposite position.

3. Notch up controller very slowly watching ammeter so as not to exceed 1,800 amperes. As soon as current falls, pull up a notch and wait until current drops below 1,800 before pulling up another notch.

Question 90. Can a train be stopped in this way when power is off the line?

Answer. Yes. If running on A. C. pull controller lever to any of A. C. positions at once. If in D. C. zone pull controller lever at once to a notch beyond D. C. shunt No. 2 and then slowly notch up to Full Multiple.

CUTTING OUT MOTORS.

Question 91. How is apparatus arranged in A. C. zone so as to operate with one pair of motors?

Answer. When running on A. C. to cut out one pair of motors:

1. Throw motor control cutout of that pair of motors, to "Out" position.
2. Open circuit breaker leading to pair of motors to be cut out.
3. Disconnect the balancing transformer on side of locomotive to be cut out, by throwing the double throw heater switch to the opposite position.

Operating with only one pair of motors a current of 2,000 amperes may be drawn but not exceeded.

Question 92. How is apparatus arranged when in D. C. zone so as to cut out a pair of motors?

Answer. It depends on which pair is cut out.

To cut out motors Nos. 3 and 4 simply throw the motor control cutout of that pair to "Out" position.

To cut out motors Nos. 1 and 2:

1. Throw their motor control cut-out to the "Out" position.
2. Open D. C. main switch. (Handle up.)
3. Raise trap door in floor over No. 1 truck and disconnect the two extreme right hand leads at the joints in the cables painted white.

Tape the ends coming from the cab, to prevent accidental grounding on the motor frame.

4. Close D. C. main switch. (Handle down.)

When operating with one pair of motors on D. C. power, locomotive is handled the same as when operating with four motors.

A current of 2,000 amperes may be drawn but not exceeded.

Question 93. Cannot one motor be cut out?

Answer. No. The motors are permanently connected in pairs. To cut out one motor the pair to which it belongs must be cut out.

FAILURE OF AIR SUPPLY.

Question 94. What will be the result of a failure of air supply?

Answer. Insufficient air to operate switch groups or air brakes.

Question 95. What is to be done when air supply fails?

Answer. There is enough air in the emergency control reservoir to operate the electric apparatus eight or ten times.

Question 96. How should apparatus be arranged to use emergency air reservoir?

Answer. In order to use emergency control reservoir it is necessary to throw handle of three-way cock on top of the reservoir to the extreme left.

Under normal conditions this handle must be left in central position.

Question 97. Is there any reserve air for air brakes?

Answer. No. So much air is required to release brakes that no emergency supply can be carried.

Question 98. How is train controlled when air supply fails?

Answer. By using the hand brakes or the motors as brakes.

TEMPERATURE OF MOTORS.

Question 99. At what temperature does operation of motors become dangerous?

Answer. If a temperature of 80 degrees or over is registered on the meters, telephone to terminal foreman for instructions before continuing the operation of locomotive.

BLOWERS.

Question 100. What parts of locomotive are cooled by air blast?

Answer. The four main motors, the two main transformers and the sets of resistance grids are cooled by air blast.

Question 101. How are the blowers operated?

Answer. There are two blowers each being a fan connected to a small motor of the same type as the main motors.

These blower motors are changed over from A. C. to D. C. by the change-over switches.

Question 102. How are blower conduits arranged?

Answer. Each blower has a conduit fitted with two dampers close to it. In the event of a blower being disabled and cut out, both these dampers must be closed as otherwise the air from the blower in service will escape

through the standing blower, without passing through the apparatus.

The conduit from each blower carries air from its own blower through one set of motors, transformer and resistance grids.

These conduits are so connected that if one blower is disabled and its two dampers closed, air from other blower will pass through both sets of apparatus.

Question 103. How are the snow screens to be used?

Answer. To prevent snow being blown into apparatus and by melting, wet the transformer and motor snow screens are to be shut during snow storms, even if very slight.

To supply air to blowers when snow screens are shut open one of the cab doors.

If storm is too severe to do this open one or two of the trap doors in the floor.

FUSES.

Question 104. What are the different fuses and where are they to be found?

Answer. The third rail shoe fuses in fuse boxes located above the third rail shoe operating cylinder.

The lighting compressor and blower fuses, one set for each side of the locomotive, located in a box above the air compressor on its own side.

The heater fuse in a box located over the emergency control reservoir.

Question 105. What is the procedure in replacing third rail shoe fuses?

Answer. 1. Open D. C. main switch.

2. Open all compressor and blower switches.

3. Open train line heater switch.
4. Insert paddles between all shoes and the third rail.
5. Replace fuse.
6. Keep well away from the fuse box as paddles are removed and the apparatus cut in.

Question 106. How are lighting, compressor, and blower fuses replaced in D. C. zone?

Answer. The lighting, compressor, and blower circuits while on D. C. are protected by a fuse, which is the central fuse in the fuse boxes located in cab.

To replace this fuse:

1. Open D. C. main switch.
2. Insert paddles between all shoes and third rail.
3. Replace fuse.
4. Remove paddles and reset D. C. main switch.

Question 107. How are lighting circuit fuses replaced on A. C.?

Answer. The top fuse in each fuse box is on A. C. lighting circuit. To replace it:

1. Open knife switch on ceiling over the relay box.
2. Open both A. C. circuit breakers.
3. Replace fuse.
4. Reset the circuit breakers, and close knife switch.

Question 108. How are blower and compressor fuses replaced on A. C.?

Answer. The lower fuse in each fuse box is on A. C. blower and compressor fuses. To replace it:

1. Open both A. C. circuit breakers.
2. Replace fuse.
3. Reset circuit breakers.

Question 109. How is heater circuit fuse replaced?

Answer. On A. C.:

1. Open the three heater knife switches.

TABLE A.

SEQUENCE OF SWITCHES WHEN OPERATING ON DIRECT CURRENT.

Position.	Notch	Sw. Gr. No. 1							No. 2		Sw. Gr. No. 3							Sw. Gr. No. 4							No. 5		Sw. Gr. No. 6					
D. C. Switching	1	1	O	O	4	5					M1							O	12	13	O	S	15							JR
	2	1			4	5					M1								12	13		S	15							JR
	3	1			4	5					M1		R1						12	13		S	15							JR
	4	1			4	5					M1		R1						12	13		S	15			RR1				JR
	5	1			4	5					M1		R1	R2					12	13		S	15			RR1				JR
	6	1			4	5					M1		R1	R2					12	13		S	15			RR1	RR2			JR
	7	1			4	5					M1			R2	R3				12	13		S	15			RR1	RR2			JR
	8	1			4	5					M1			R2	R3				12	13		S	15				RR2	RR3		JR
	9	1			4	5					M1				R3	R4			12	13		S	15				RR2	RR3		JR
D. C. Series	10	1			4	5					M1				R3	R4			12	13		S	15					RR3	RR4	JR
D. C. Shunt No. 1	11	1			4	5	8				M1					R4			12	13		S	15	18				RR3	RR4	JR
D. C. Shunt No. 2	12	1			4	5	8	9			M1					R4			12	13		S	15	18	19			RR3	RR4	JR
	13	1			4	5	8	9			M1					R4	J		12	13		S	15	18	19			RR3	RR4	JR
	14	1			4	5	8	9			M1						J		12	13		S	15	18	19					
	15	1			4	5	8	9			M1	G1					J		12	13		S	15	18	19	M2				
	16	1			4	5	8	9			M1	G1							12	13		S	15	18	19	M2				
	17	1			4	5					M1	G1	R1						12	13		S	15			M2	RR1			
	18	1			4	5					M1	G1	R1	R2					12	13		S	15			M2	RR1	RR2		
	19	1			4	5					M1	G1		R2	R3				12	13		S	15			M2		RR2	RR3	
D. C. Full Multiple	20	1			4	5					M1	G1			R3	R4			12	13		S	15			M2			RR3	RR4

NOTE:—O—Switches 2, 8 11 and 14 used when moving in reverse direction.

SEQUENCE OF SWITCHES WHEN OPERATING ON ALTERNATING CURRENT.

Position.	Notch	Sw. Gr. No. 1							Sw. Gr. No. 2									Sw. Gr. No. 4							Sw. Gr. No. 5								
	1	1	O	O	4	G2	6	7										O	12	13	O	16	17										
	2	1			4	G2	6	7											12	13		16	17										
A. C. Switching.	3	1			4	G2	6	7	I										12	13		16	17	I′								
	4	1			4	G2	6	7	I	II									12	13		16	17	I′	II′							
	5	1			4	G2	6	7	I	II	III								12	13		16	17	I′	II′	III′						
A. C. No. 1	6	1			4	G2	6	7	I	II	III	IV							12	13		16	17	I′	II′	III′	IV′					
A. C. No. 2	7	1			4	G2	6	7		II	III	IV	V						12	13		16	17		II′	III′	IV′	V′				
A. C. No. 3	8	1			4	G2	6	7			III	IV	V	VI					12	13		16	17			III′	IV′	V′	VI′			
A. C. No. 4	9	1			4	G2	6	7				IV	V	VI	VII				12	13		16	17				IV′	V′	VI′	VII′		
A. C. No. 5	10	1			4	G2	6	7					V	VI	VII	VIII			12	13		16	17					V′	VI′	VII′	VIII′	
A. C. No. 6	11	1			4	G2	6	7						VI	VII	VIII	IX		12	13		16	17						VI′	VII′	VIII′	IX′

TABLE B.

VOLTAGES GIVEN BY SWITCH GROUPS 2 AND 5.

Switches I and I′ are corresponding switches in switch groups 2 and 5. Each gives same voltage to its own pair of motors.

Switch.	Voltage.
I	239
II	291
III	345
IV	397
V	450
VI	495
VII	548
VIII	584
IX	636

2. Replace fuse.
3. Close the switches.

On D. C.:

1. Open train line heater switch.
2. Insert paddles between all shoes and third rail.
3. Replace fuse.
4. Remove paddles and close heater switch.

SANDERS.

Question 110. How should an air leakage through the sanding valves be remedied?

Answer. The sander should be cut off by closing shut-off cock provided for that purpose.

If this is not done the pressure in main reservoir may be lost.

Question 111. What are the most important things to remember in these rules?

Answer. Never allow current to flow in a motor which is standing still.

Never use water on a fire.

Never use a crow bar or a coupler pin around the locomotive.

Never go on top of locomotive while a trolley is in contact with any wire.

INDIANA UNION TRACTION COMPANY'S ELECTRIC LOCOMOTIVE.

Fig. 202 shows a type of electric locomotive recently put in service on the lines of the Indiana Union Traction Company, Anderson, Indiana. The locomotive is the steeple cab, sloping end type and has the following general dimensions:

Total weight on drivers	100,000 lbs.
Extreme length (over steps)	33′ 6″
Extreme length over couplers	33′ 5″
Extreme length over bumpers	31′ 2″
Extreme width	8′ 6″
Extreme height (rail to clearance line)	13′ 5″
Height of trolley board above rail	12′ 7″
Width of bumper	1′ 0″
Height to center of couplers	35½″
Truck centers	6′ 0″
Center to center of bolsters	17′ 11 11/16″

TRUCKS. The trucks under this locomotive are of the Baldwin Master Car Builders equalizing bar design. The frame is of wrought iron, filled together with steel channel transoms at the center and steel angle bars at the ends. The transom channels and angle bars are fitted together at the junction to the frames with steel gusset plates. The pedestals are made of wrought iron carefully machined to fit the truck frames, and also machined between pedestal jaws to fit the journal boxes. The whole structure of these trucks is fitted

Fig. 202.

together by machine turned bolts driven into holes reamed out to receive them. The truck bolsters are made of wrought iron, the weight on the bolster being supported by double elliptic, twelve leave springs. These elliptic springs rest on a steel spring plank, hung by swinging links from the track transoms. The entire truck frame supporting the locomotive rests on four coil springs, transmitting the weight of the locomotive to four steel equalizing bars which rest on the journal boxes. The journal boxes are of the Master Car Builders interior design, and have cast on them extensions to which a beam may be bolted to carry a collector, should it be desirable to use the third rail means of transmitting current.

The brake rigging is of the inside hung type with one live lever, and one dead lever on each side of the trucks. The motor suspension employed on these trucks is of the "Gibbs" type. This consists of a rectangular frame of wrought steel, to which both motors are attached by swing bolts on each side of the motors, and spring supported bolts at one end of the motor. This type of motor suspension has the following advantages:

a—No part of the motor weight is carried on the truck frame.

b—The motor suspension springs need to be only of sufficient strength to carry the weight of the motors, hence the motors ride more easily, are subject to less jar, and have less hammer blow effect on the track than with any other form of motor suspension.

c—With this form of motor suspension the entire truck frame may be removed from the axles without disturbing the motors.

The principal dimensions of the trucks are as follows:

Gauge ..... 4′ 8½″
Height of center plate above rail..... 2′ 9 ″
Wheel base ..... 6′ 0 ″
Weight of truck complete without motors ..... 10,000 lbs.
Designed to carry..... 25,000 lbs.

TRUCK CONSTRUCTION.

Side frames wrought iron..... 2″x3¾″
Pedestals wrought iron..... 2″x4½″
Center transoms..... 10″ channel
Truck bolster wrought iron..... 9″ wide
Bolster truss steel plate..... ⅞″x7½″
Center plate..... Cast steel
Equalizing bars wrought iron..... 1″x6″
Spring plank—steel ..... 1″x3″

SPRINGS.

Double elliptic, 12 leaves..... 28 ″
Single coil, diameter..... 7½″

WHEELS AND AXLES.

Wheels cast steel spoke center steel tires... 33″
Tires held by "Gibson" retaining rings ..... 2⅞″x3⅞″
Axles at center..... 6½″
Gear and wheel seat..... 7½″
Journals ..... 4¼x8″
Journal boxes..... M. C. B. cast iron

ELECTRIC EQUIPMENT.

Trucks designed for two Westinghouse No. 85 railway motors rating 75 H. P. each.

MOTOR SUSPENSION.

"Gibbs" cradle suspension.

MOTORS. The motors on this locomotive are Westing-

house No. 85. The frame is made of cast steel, divided horizontally in two parts, securely bolted together, and forming a field which is wholly ironclad, and approximately cylindrical in shape. The design is such that when mounted on the truck, the holding bolts may be withdrawn and the upper field lifted off. To this end the suspension lugs, and projection for the support of the gear case are cast with the lower field.

A large opening with a spring-locked cover is provided in the upper casting, which permits access to the commutator and brushes. Hand-holes are provided in convenient locations about the motor frame.

The four pole pieces are built up of soft steel punchings, riveted together between end plates of wrought iron, and are held to the motor frame by bolts. The poles project radially inward at angles of 45° with the horizontal. Two bolts, secured by lock washers, hold each pole piece in place. They do not penetrate the pole face, but terminate in heavy rivets inside the pole made for this purpose. A smooth and unbroken pole face is thus presented to the armature.

The poles are made with projecting tips, which properly distribute the magnetic field, and also serve to retain the field coils, which are held firmly in place by spring washers. The coils are wound with asbestos-covered wire. They are heavily taped, and are treated with specially-prepared insulating compounds which render them practically moisture proof. The armature core is formed of circular punchings of soft steel, built up upon a cast iron spider. Ventilating spaces are provided in the core at right angles to and parallel with the shaft. There is, therefore, a thorough circulation of air through the core, and through, and about the coils, insuring an even dis-

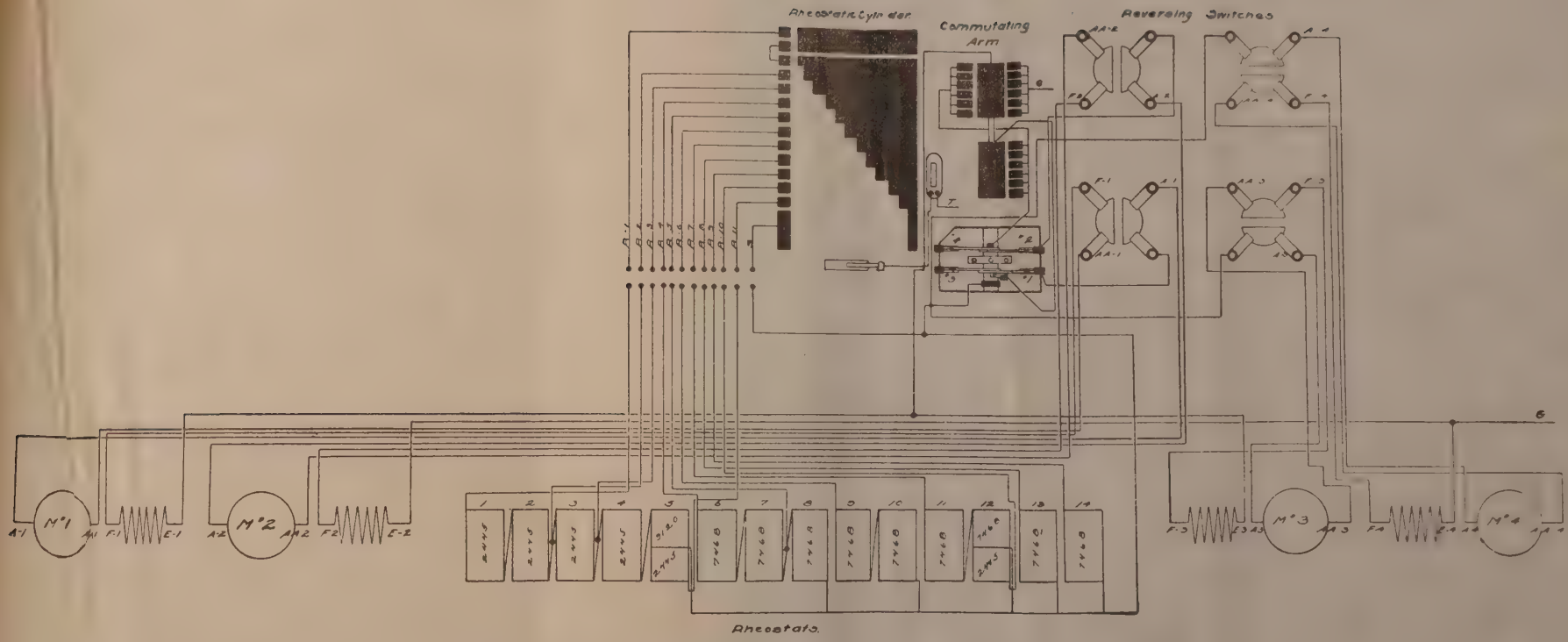


Fig. 203. Wiring Diagram of Union Traction Co.'s Electric Locomotive No. 679.

tribution of the heat developed, and its rapid radiation. The spider is pressed on and keyed to the shaft. The commutator also is mounted on the same spider, and the shaft can thus be taken out and renewed should this be necessary, without disturbing any other part.

The armature is wound with machine-formed coils, imbedded in rectangular open slots, and held in place by band wires sunk in grooves. It is therefore wholly iron-clad, and the winding protected against mechanical injury. Canvas caps protect the winding at both ends, completely covering the parts of the windings outside of the armature core. The end plate at the pinion end is provided with a bell-shaped flange, upon which the windings rest. This flange also holds the ends of the coils rigidly in place. The armature may, therefore, be run safely at high speeds. The ends of the coils, and the back of the commutator are thoroughly protected from carbon and copper dust. The complete armature is 15¾ inches in diameter.

Wiper rings of approved design pressed upon the shaft outside the armature revolve in spaces in the motor frame inside the bearing boxes, and prevent oil working its way along the shaft to the commutator or winding. Oil thrown off by these rings is drained off through suitable openings.

The commutator consists of 117 hard-drawn copper segments with short necks, separated by prepared mica sheets, built up upon a cast iron bushing, and clamped between two V-shaped surfaces, from which they are insulated by similarly-shaped rings of moulded mica. The completed commutator measures 12 inches in diameter by 4¾ inches in width, and has a wearing depth of approximately one inch. It is pressed on, and keyed to the armature spider.

Brush holders of the sliding shunt type are mounted on cast brass arms which are secured to the motor frame by vulcabeston headed bolts. These arms admit of radial adjustment to compensate for wear of the commutator. The tension springs may be thrown back and fastened out of the way, facilitating the inspection of the brushes.

Each arm carries two carbon brushes ½″x2″ in section. The tension springs for each brush are independently adjusted.

Flexible leads of rubber insulated cable are brought out through bushings of semi-hard rubber, set in the motor frame.

Curve sheet shows the characteristic curves of this motor under conditions of variable load, as found in locomotive practice.

Controller. The controller is of the L-4 type of series parallel controller, and the accompanying diagram (Fig. 203) shows the wiring arrangement of motors and resistance steps from zero to full multiple operation.

Steel Underframe. The underframing of this locomotive consists of two center sills, two side sills, two end sills, two bolster sills and its diagonal bracing.

The center sills consist of two 12″x12″ plate girders composed of ¼x12″ plate with four angles 6x3½ riveted together.

The side sills are 12″, 31½ lbs., "I" beams.

The end sills are of the same plate girder section as the center sills fitted into the sills, and riveted together by ⅝x10x11¼″ angles and ¾″ rivets.

The bolsters are also made of 12″ plate girders fitted in between the side and center sills, and have reinforced top and bottom cover plates 1″x8″ riveted to all sills.

The diagonal braces are ½″x6″ riveted to all sills top and bottom.

The center plates are fitted over the bottom cover plates, and are bolted on with four 1″ bolts.

The draw bars are of the M. C. B. standard type, and they are connected to the center sills at each end of the steel framing, by channel steel spring pocket plates, riveted by ¾″ rivets to the two 12″ plate girders which constitute the center sills.

Locomotive Body Framing. The body framing is of oak. The cab which is located in the center is 7′ 8″ square, and is provided with windows in the ends, sides, and doors, affording the operator a good view of the track while operating the locomotive in either direction. The body flooring, which extends to within 12″ of each end is 2″ of tongued and grooved pine. The outside sheeting, which extends clear down to the bottom of the side sills, is tongued, matched and grooved poplar.

The inside sheeting of the sloping portion is 1″ tongued and grooved pine.

The outside of the sloping portion is covered by sheet iron of the No. 27 gauge.

In the floor of the cab there is provided a trap door, giving access to a convenient tool box arranged between the steel sills of the underframing.

The roof of the cab is sheeted over with poplar and painted canvas to make it weather proof.

The locomotive body is securely bolted through the steel underframing, and the sloping ends are arranged to receive the ballast necessary to give the locomotive the proper weight on the drivers.

Brakes. The locomotive is fitted with the latest type of Westinghouse automatic quick action brakes, so that it may handle steam, or electric cars fitted with automatic brakes. It is also fitted out with the Christensen

straight air brake, so that it may handle electric freight or passenger cars equipped with straight air. By an ingenious arrangement the two engineer's valves, conveniently located, are made to interlock each other so that when it is desired to use the automatic air brake the engineer's valve on the straight air line is locked and cannot be operated, or when it is desired to use the straight air brake the engineer's valve on the automatic line is locked, and cannot be moved. This arrangement was made necessary to avoid any confusion, and possible accident due to operating the wrong valves.

Air for the locomotive and its train is provided by an electric driven air compressor of 25 feet capacity, located in the locomotive cab. This is provided with a pneumatic electric governor which cuts off the current from the compressor motor when the pressure in the air tanks reaches 110 lbs. and automatically cuts it in when the pressure is reduced in the main reservoir to 95 lbs. The necessary air gauges, switches, etc., are located in the cab, indicating main auxiliary and train line air pressures. The main and auxiliary air reservoirs are located underneath the steel framing.

The locomotive is equipped with a double pneumatic sanding device on front, and rear trucks, so that sand may be delivered to front or rear trucks separately, or simultaneously in either direction. The sanding valves are located in the cab convenient to the operator.

Bell. There is also provided a 14″ locomotive bell, of ornamental design, located on one of the sloping ends of the body. This bell is swung by an air cylinder. When it becomes necessary to ring the bell, the operator turns a small valve in the cab, and the bell continues to ring till the air is shut off. This arrangement allows the

operator free use of both hands for his controller, and air brakes.

Light. An electric arc searchlight is furnished on both ends of the locomotive, so that the operator may have a clear view of the track at night going in either direction.

Trolley Retrievers. Trolley retrievers are also furnished at both ends, to take care of the trolley pole rope in normal condition, when the trolley wheel is on the wire. Should the wheel leave the wire, the retriever promptly pulls the pole down, preventing any destruction of the overhead wires, and transmission lines.

Trolley Base. The trolley base is of the most approved ball bearing type, permitting a ready response of the trolley wheel to any changes of alignment, or varying height of the transmission wire.

Marker Lights. Electric marker lights are provided under the roof of the cab at both ends, permitting the display of two green, two white or two red lights. These lenses are 5¼″ diameter and are arranged in accordance with the rules of the Central Electric Railway Association, governing the use of classification and tail lights.

This locomotive is one of the notable examples of a high speed, high grade engine, which may be used in freight or passenger service and has been designed and constructed so that it may be used in the company's own business or it may serve to interchange and handle the cars of foreign lines, either steam or electric, as all its equipment will interchange with the Master Car Builders' Standards of steam roads.

ENCLOSED ARC HEADLIGHT EQUIPMENT FOR STREET RAILWAY SERVICE.

FORM B.

The equipment consists of two parts: the headlight, including cable, plug and two sockets; and the rheostat.

TO PREPARE HEADLIGHTS FOR INSTALLING.

When the headlights are received and unpacked, open the glass door and remove all shipping ties from the mechanism. Carefully brush out all dust, etc., that may have accumulated. Examine the mechanism for loosened parts.

INSTALLING THE SYSTEM.

Connections should be made according to the diagram (Fig. 204), with the rheostat installed in a vertical position where there is a free draft of air. Be sure that the car dasher is grounded to the negative side of the line. That the headlight may be interchangeable for either end of the car, each platform should be furnished with one of the sockets, to which the headlight can be attached as shown.

Where it is desired to use incandescent lamps in place of the resistance, and thus utilize for car lighting the power otherwise lost, lamps should be connected in multiple series so as to supply 4 amperes, and 80 volts to the headlight under average operating conditions.

ADJUSTING THE HEADLIGHT.

All equipments are carefully adjusted and tested before shipment. If the installation is made as above directed, no readjustment should be necessary. With the resistance in series with the headlight, and a 520 volt line there should be approximately 4 amperes 80 volts at the arc. The current is dependent upon the amount of resistance in circuit, and the arc voltage depends upon the arc length or, in other words, upon the position of the stop which limits the upward movement of the carbon clutch.

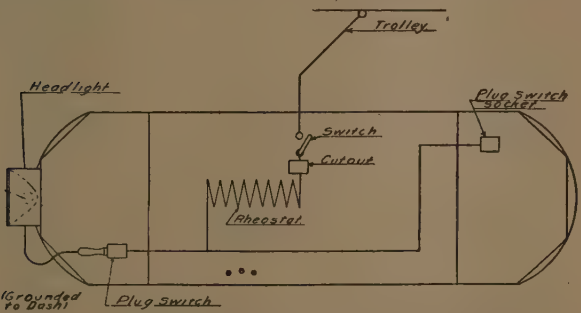


Fig. 204. Connections of Enclosed Arc Headlight Equipment for Street Railway Service, Form B.

The lower carbon should be raised slightly from time to time to keep the arc in focus.

CONNECTING.

Hang the headlight on the dasher and insert the plug in the socket. When properly connected in circuit the upper carbon is positive.

ENCLOSING GLOBE.

The headlight should never be used without the enclosing globe which excludes the air from the arc. The enclosing globe should be properly fitted at the bottom so as to make an air-tight joint. The upper edge of the globe must rest squarely against the cap. The number of hours the lamp will burn with one trimming depends largely upon keeping the globe tight and excluding the air.

REFLECTOR.

The reflector in front of the lamp mechanism is held in place by two screws. The inside surface should be kept clean and bright.

CARBONS.

Only the best grade of solid carbons of the following dimensions should be used:

Upper, 6″ long x ⅜″ diameter.

Lower, 4″ long x ⅜″ diameter.

Maximum allowable dia. of ⅜″ carbons .400″.

Minimum allowable dia. ⅜″ carbons .390″.

The total burning time of the above carbons should be about 24 hours.

TRIMMING THE HEADLIGHT.

As carbons vary somewhat in diameter, only those within the limits specified should be used. The carbons should pass freely through the enclosing globe cap, for

any friction at this point will prevent the proper operation of the lamp. Be sure the carbons are smooth and straight.

To carbon the headlight, disconnect it from the circuit, and remove the lower carbon by opening the supporting spring at the bottom. The inner globe should be removed, cleaned and replaced, returning the holder to its proper position by bringing the top of the carbon to the focus of the reflector. Remove the cap on the top of the headlight and drop the upper carbon into the carbon tube. Replace the cap.

RECENT DEVELOPMENTS OF LIGHTNING ARRESTERS.

Ordinarily a lightning discharge, which is an equalization of potential between the earth, and either clouds or saturated atmosphere above the earth, will take place through the path of least resistance, but, as pointed out by Rowland, there is a certain factor somewhat resembling inertia which causes the lightning, once started, to follow sometimes an irregular path, similarly, for instance, as when a piece of paper is suddenly torn. Transmission lines and buildings of ordinary height surrounded by trees are not peculiarly subject to damage from lightning, because they cover a comparatively small portion of the earth, and are surrounded by objects of greater height, which offer a better path for the lightning discharge to the earth. They do, however, receive some discharge, and the damage which might be done can be very great. It is, therefore, necessary to provide ample protection.

Generally speaking, the severe manifestations of lightning are confined to a relatively small area, which rarely exceeds in extent an area of about one square mile. It may be concluded from this that protective apparatus situated at certain points along the line will afford no protection to remote points.

Generally speaking, the broad requirements for lightning protection consist in supplying paths to ground for any charge which might accumulate on lines, or machinery from any cause whatever. The ideal arrester

will cause excessive potential differences to be relieved instantaneously, and stop the flow of current, as soon as the potential has fallen to safe limits for the line. No one type of lightning arrester fulfills all requirements, and accordingly it is found expedient to use different types and combinations, in different situations and under different conditions.

For the protection of electric circuits, grounded guard wires are best, and when the cost over the whole system would prove prohibitive, they should be confined to such localities as are peculiarly liable to suffer destructive discharges. Three ground wires are required for the best practicable protection. One of these should be placed on top, and in the middle of the line, and should be a heavy galvanized steel cable, and the other two, which should be heavy telegraph wires, are placed outside, and above the top side conductors. The ground wires should be earthed at every pole for the first 10 or 12 poles from the building, and at every second pole on the rest of the line. Graded resistance or aluminum type lightning arresters should be installed on every feeder issuing from the station, and on primary and secondary of every transformer, and a surge protector in the station, but choke coils having a large number of turns should not be used in the station, as they represent a possible source of danger.

Lightning may consist of a single discharge of great violence and very small duration, or it may consist of a great number of distinct discharges following each other rapidly and each lasting only a very short time. Thus the same path may serve for a great number of short discharges closely following each other. The total time of passage and number of discharges have been deter-

mined by Alex. Larsen from photographic records made with a revolving camera. In an extreme case, 48 flashes were recorded in a total interval of .624 second. This establishes the unsuitability of arresters depending upon moving parts for their operation. Such arresters might possibly leave the line unprotected during a minute interval of time, which might be of momentous magnitude in comparison with the very brief period of duration of a single lightning flash.

Where from internal causes, such as flashing over a bushing or insulator, the arcing ground sends a series of oscillations through the circuit, it is necessary to provide an arrester which will continue to discharge the abnormal voltage for a sufficient period to permit the operator to locate and isolate the trouble. Half an hour is generally found to suffice for the period of an arrester, as this will give time to discover the point of trouble, where this is remote from the station.

Horn arresters placed along the line at various places will do much to protect insulators from puncturing or arcing across. These horn arresters should be adjusted to arc at something below the wet arc-over voltage of the insulators, and should be connected to earth direct. Only one phase per pole should be protected by a horn arrester, so that in the event of two horns arcing simultaneously, the earth resistance can be utilized to limit the discharge. Ground wires should not be grounded at poles carrying horn arresters.

Lightning rods above wooden poles are an advantage. Graded resistance multigap, or aluminum arresters should be used on outgoing and incoming lines. Choke coils should be in the circuit just back of arresters, which, in turn, are placed quite near the passages and

are provided with disconnecting switches. Single-phase locomotives have a specially designed graded resistance multigap type of arrester, which meets the requirements of space limitation.

For voltages exceeding 35,000 the aluminum, or electrolytic type of arrester should be recommended exclusively, and even for moderate, and low voltages they are so far superior to other types that their ultimate selec-

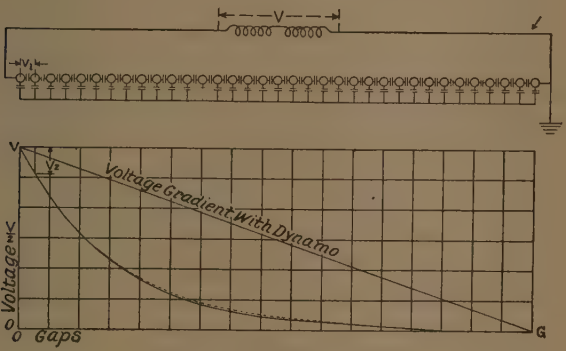


Fig. 205. Lightning Arrester.

tion reverts to a question only of initial cost. Aluminum arresters are designed especially to take care of recurrent, or continuous discharges, which are, as a rule, of comparatively low frequency, and therefore travel over the entire system, so that even if the system is supplied with multigap arresters, it is advisable to install one or more aluminum arresters having low adjustment. This arrangement will prevent the other types of arresters from discharging continuously until they are injured.

The general theory of the multigap arrester is as follows: When voltage is applied across a series of multigap cylinders, the voltage distribution is not uniform. The voltage distributes according to the capacity of the cylinders, both between themselves and also to ground, and the capacity of the cylinders to ground, results in the concentration of voltage across the gaps nearest the line. Fig. 205 shows the theoretical voltage gradient along an arrester. The voltage across the end gaps reaches a certain value. They are across, passing the strain back to the other gaps, which in turn are over until the spark has passed entirely across. The arrester in this manner arcs over at voltage much lower than would be required if the voltage distributed evenly. When the arrester has arced over, and current is flowing the voltage then does distribute evenly between the gaps, and is for this reason too low to maintain an alternating current arc. The arc, therefore, lasts only to the end of a half cycle, and then goes out. The maximum voltage per gap at which the arc will extinguish at the end of the half cycle depends to a great extent upon the metal of the cylinders. Thus some metals are more efficient than others in extinguishing the arc. When the voltage of an alternating current passes through zero, of course no current flows. Before the current flows in the reverse direction the voltage must again break through the dielectric. The voltage required to do this depends upon how much the dielectric has been weakened by the passage of the arc. The cooler the arc, the less the dielectric is weakened, and the higher will be the voltage required to reverse the arc. As the temperature of the arc depends upon the boiling point of the cathode metal, in very much the same way as the temperature of steam

depends upon the boiling point of the water, metals with low boiling points are used for the lightning arrester cylinders, in order to keep down the arc temperature.

The use of resistance in a lightning arrester needs very careful consideration. Lightning does not readily pass through resistance, especially when in series with multigaps, and therefore series resistance should not be used. At the same time it is very desirable in some way to limit the current. This problem has at last been solved by use of a low shunt resistance, shunting a part of the gaps and so proportioned to divert the current from the gaps, after the discharge has passed the ground. Shunt resistance has been used before, but never for this purpose, and was never made low enough to divert the arc in this way.

It is obvious, of course, that a discharge taking place through a high resistance will not relieve the line except in a case of the static. What happens, however, is something like this: When a surge of dangerous voltage rises, and before it reaches a danger point, the series gaps arc over. The series gaps then being practically short-circuited by the arc the voltage concentrates across the lowest division of the shunted gaps, and these at once also break down. The current is then limited by the medium resistance, and the voltage is concentrated across the second division of the arrester. If these gaps break down, the discharge is limited only by the low resistance, which should take care of most cases. If necessary, however, the voltage can "break back" in this way, and cut out all resistance. The number of gaps to rectify depends largely on the current that flows. In this arrester the number of gaps discharging increases

as the limiting resistance decreases. The arrester will, therefore, operate and extinguish the arc at the end of the half-cycle no matter which path the current takes.

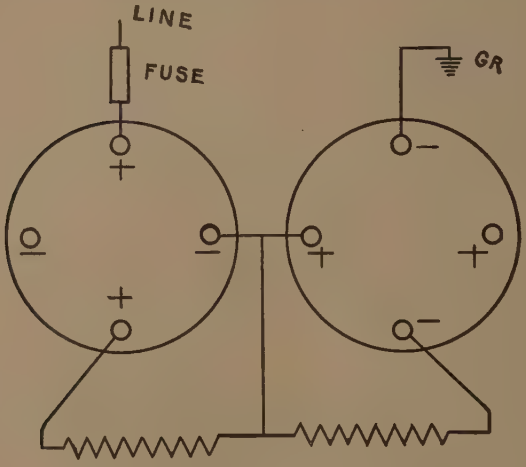


Fig. 206. Station Arrester.

INSTRUCTIONS FOR INSTALLING 600 VOLT D. C. ALUMINUM LIGHTNING ARRESTERS.

The principal elements of this arrester are two cells, each consisting of two concentric aluminum plates immersed in an electrolyte contained in a glass jar.

The outside plate of each cell should be the positive, and the inner one the negative, as indicated by the marking of the four studs on the porcelain cover, two studs supporting each plate.

In addition, station arresters are fitted with a balancing resistance in shunt with each cell and a series fuse; car arresters, with a series fuse as connecting link between the two cells. Diagrams of connections are shown in Figs. 206 and 207.

To Fill the Arrester. Unscrew the metal rings at the top of the jars and lift off the porcelain covers, with

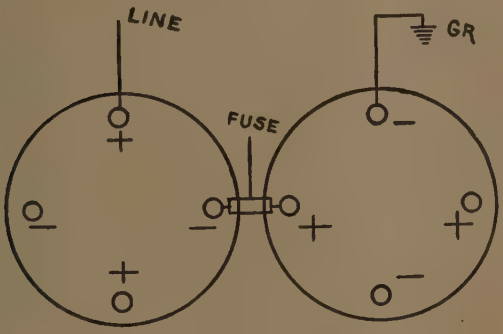


Fig. 207. Car Arrester.

the aluminum plates attached, without removing the connection between the two units. Pour enough electrolyte into the jars to bring the level to about one inch from cover. Add ⅛ pint of oil to each jar.

In transferring the electrolyte, or oil from the carboy, or other container used for shipping, employ nothing but clean aluminum, or glass vessels and funnels. Take every precaution to prevent any dust or other material from getting into the electrolyte.

IMPORTANT.

Although the cells are shipped with film in prime condition, we have found it advisable before connecting permanently to the circuit to connect the arrester in series with five 120 volt incandescent lamps across the 600 volt circuit. The lamps will burn brightly for an instant and then rapidly diminish to darkness, thus indicating that the film is all right. If the lamps are dark at first, the circuit should be opened and closed, and a small snappy spark at the contact point will show that the circuit is complete and the film in proper condition. The lamps should then be removed and the cells connected directly to the circuit.

Connections. These should be as short as possible between line and ground, and only to those points on which the terminals are placed when shipped. Use only the style of terminal furnished, as they afford no chance for a short circuit by swinging against the opposite terminal. In the case of pole arresters the test with series lamps, as described above, should be made before making the last connection, otherwise there may be a considerable flash due to an instantaneous current rush. The ground connection of these line arresters should be made directly to the rail, or ground bus, and driven pipe ground.

Operation. If the arrester has stood assembled in its electrolyte for a month or more, when reconnected there will be a momentary rush of current which may amount to several hundred amperes. To avoid this current rush use lamps in series as explained above.

It is preferable, however, when an arrester is to be

left out of service for some time, to pour out the electrolyte and oil, wash the plates and jars with clean water and put the plates back in the jar. When replacing in service, make the usual test with lamps.

After operating for some time, arresters without balancing resistance, may divide the voltage unequally between cells, which is indicated by sparkling of the plates in one cell. Hence, car arresters which have no balancing resistances should be inspected frequently, say once a month, and when sparkling is noted, the arrester should be removed from the circuit, and connected to a test circuit with a bank of five lamps in shunt with each jar; that is ten lamps from line to line with the middle point connected between cells. After operating this way for several hours remove the lamps. If sparkling has ceased, the arrester is ready to be returned to the car.

After the arrester has been in operation for a short time, the electrolyte may become dark in appearance, but this condition is normal.

Inspection should cover answers to the following questions:

1. Are there any loose connections?
2. Is the level of the electrolyte at the proper height?
3. Are the positive plates worn off at the surface of the electrolyte?
4. Are the connecting leads as short as possible?
5. Does either cell sparkle?

Remember that the tests with series lamps should always be used with the arrester, as explained under "Important," before it is connected for the first time to the circuit, or after it has been out of service for a month or more.

MULTIGAP LIGHTNING ARRESTERS FOR ALTERNATING CURRENTS.

These arresters, designed upon an elaboration of Prof. Elihu Thomson's fundamental patents, consists of a series of spark gaps shunted by graded resistances, but without series resistance. The advantages possessed by them are:

1. Uniform voltage discharge over a wide range of frequency due to graded resistance.
2. Shunting the dynamic current through resistance.
3. The "breaking back" action on low frequency surges.
4. Fuse in ground leg of non-grounded neutral systems.
5. Adjustable gap in each leg shunted by a fuse.
6. Metallic resistance rods of improved composition.
7. Durable knurled cylinders of special alloy.
8. General Electric standard multiplex connection.

When properly installed they will perform the following functions:

First. Prevent excessive rise of potential of a transitory nature between lines, as well as between lines and ground.

Second. Restrain the flow of electric current across the gaps, and extinguish the arc when normal potential is restored.

Third. Discharge high potentials covering a wide range of frequency.

The essential elements of the arrester are, a number of cylinders spaced with a small air gap between them and, placed between line and ground, and between line

and line. In operation the multigap arrester discharges at a much lower voltage than would a single gap having a length equal to the sum of the small gaps.

In explaining the action of multigaps, there are three things to consider:

1. The transmission of the static stress along the line of cylinders.

Fig. 208. Arrangement of Resistances.

2. The sparking of the gaps.

3. The action and duration of the dynamic current which follows the spark, and the extinguishment of the arc.

A spark may be defined as conduction of electricity by the air, and an arc as conduction of electricity by vapor of the electrode.

Distribution of Static Stress Along Cylinders. The cylinders of the multigap arrester act like plates of condensers in series. This condenser function is the essential feature of its operation. When a static stress is applied to a series of cylinders between line and ground (Fig. 208), the stress is instantly carried from end to end. If the top cylinder is positive it will attract a negative charge on the face of the adjacent cylinder,

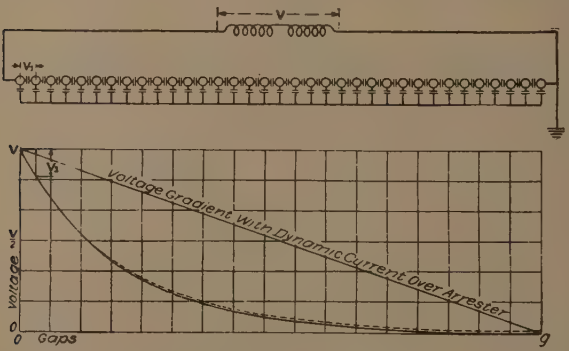


Fig. 209. Diagram Showing Condenser Action of Cylinders and Potential Gradient for Static Stress.

and repel an equal positive charge to the opposite face, and so on down the entire row. The second cylinder has a definite capacity relative to the third cylinder and also to the ground; consequently the charge induced on the third cylinder will be less than on the second cylinder, due to the fact that only part of the positive charge on the second cylinder induces negative electricity on the third, while the rest of the charge induces negative electricity to the ground. Each successive cylinder.

counting from the top of the arrester, will have a slightly smaller charge of electricity than the preceding one. This condition has been expressed as a "steeper potential gradient near the line."

Sparking of the Gaps. The quantity of electricity induced on the second cylinder is greater than on any lower cylinder, and its gap has a greater potential strain across it as shown by Fig. 209. When the potential across the first gap is sufficient to spark, the second cylinder is charged to line potential and the second gap receives the static strain and breaks down. The successive action is similar to overturning a row of ninepins by pushing the first pin against the second. This phenomenon explains why a given length of air gap concentrated in one gap requires more potential to spark across it, than the same total length made up of a row of multigaps. As the spark crosses each successive gap, the potential gradient along the remainder readjusts itself.

How the Dynamic Arc is Extinguished. When the sparks extend across all the gaps the dynamic current will follow if, at that instant, the dynamic potential is sufficient. On account of the relatively greater current of the dynamic flow, the distribution of potential along the gaps becomes equal, and has the value necessary to maintain the dynamic current arc on a gap. The dynamic current continues to flow until the potential of the generator passes through zero to the next half cycle, when the arc-extinguishing quality of the metal cylinders comes into action. The alloy contains a metal of low boiling point which prevents the reversal of the dynamic current. It is a rectifying effect, and before

the potential again reverses, the arc vapor in the gaps has cooled to a non-conducting state.

BASIC PRINCIPLES OF GENERAL ELECTRIC MULTIGAP LIGHTNING ARRESTERS.

Rectification. The greater the value of the dynamic current, the greater the number of gaps required to extinguish the arcs.

Shunting by Resistance. Any arc is unstable and can be extinguished by placing a properly proportioned resistance in parallel with it.

Effect of Frequency. The higher the frequency of the lightning oscillation, the more readily will the multigap respond to the potential.

Briefly stated, the problem is to properly limit the dynamic current, so that the arc may be extinguished; to arrange a shunt circuit so that the series resistance will be automatically cut out if safety demands it on account of a heavy lightning stroke and, while retaining these properties, to make the arrester sensitive to a wide range of frequencies. It should be noted that series resistance limits the rate of discharge of the lightning, as well as of the dynamic current.

GRADED SHUNT RESISTANCE.

The desired result is obtained in the General Electric Multigap Lightning Arresters by the use of *graded shunt resistance.* Without regarding the "cumulative" or "breaking back" effect of the graded resistance, described later, this type of arrester may be considered as

four arresters in one. First, for small discharges there are a few gaps in series with a high shunt resistance. This part of the arrester will safely discharge accumulated static, and also all disruptive discharges of small ampere capacity. In Fig. 210 this path is shown through *H* (resistance) and *GS* (gaps). Second, there are a

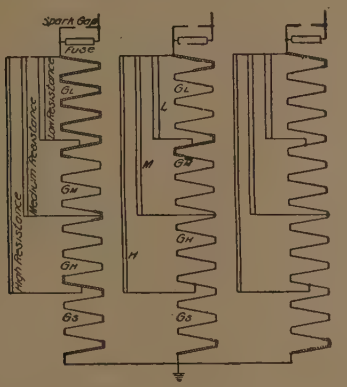


Fig. 210. Connections for 33,000-volt Y System with Grounded Neutral.

number of gaps in series with a medium shunt resistance which will discharge disruptive strokes of medium ampere capacity; in Fig. 210 this path is shown through *M* (resistance) and *GH* plus *GS* (gaps). Third, there is a greater number of gaps in series with a low shunt resistance which will discharge heavy disruptive strokes. In the figure this path is shown through *L* (resistance) and *GM* plus *GH* plus *GS* (gaps). Fourth and last, the total number of gaps has no series resistance, thus enabling the arrester to freely discharge the heaviest

induced strokes. In Fig. 210 this path is shown through zero resistance and *GL* plus *GM* plus *GH* plus *GS* (gaps).

In each of the above circuits the number of gaps, and the resistance are so proportioned as to extinguish the dynamic arc at the end of the half cycle in which the lightning discharge takes place.

THE "CUMULATIVE" OR "BREAKING BACK" EFFECT.

The graded shunt resistances give a valuable effect not brought out in the previous description, where the arrester is considered as four separate arresters. This is the "cumulative" or "breaking back" action.

When a lightning strain between line and ground takes place, the potential is carried down the high resistance, *H*, to the series gaps, *GS*, and the series gaps spark over. Although it may require several thousand volts to spark across an air gap, it requires relatively only a few volts to maintain the arc which follows the spark. In consequence, when the gaps *GS* spark over, the lower end of the high resistance is reduced practically to ground potential. If the high resistance can carry the discharge current without giving an ohmic drop sufficient to break down the shunted gaps *GH*, nothing further occurs—the arc goes out. If, on the contrary, the lightning stroke is too heavy for this, the potential strain is thrown across the shunted gaps, *GH*, equal in number to the previous set. In other words, the same voltage breaks down both of the groups of gaps, *GS* and *GH*, in succession. The lightning discharge current is now limited only by the medium re-

sistance, *M*, and the potential is concentrated across the gaps, *GM*. If the medium resistance cannot discharge the lightning, the gaps *GM* spark, and the discharge is limited only by the low resistance. The low resistance should take care of most cases, but with extraordinarily heavy strokes and high frequencies, the discharge can "break back" far enough to cut out all resistance. In the last step the resistance is relatively low in proportion to the number of shunt gaps, *GL*, and is designed to cut out the dynamic current instantly from the gap, *GL*. The illustration (Fig. 214) of the 2,200 volt arrester shows that the low resistance actually performs this function. This "breaking back" effect is valuable in discharging lightning of low frequency, in a manner better than has been obtained before.

After the spark passes, the dynamic arcs are extinguished in the reversed order. The low resistance, *L*, is proportioned so as to draw the dynamic arcs instantly from the gaps, *GL*. The dynamic current continues in the next group of gaps, *GM*, until the end of the half cycle of the generator wave. At this instant the medium resistance, *M*, aids the rectifying quality of the gaps, *GM*, by shunting out the low frequency dynamic current of the generator. On account of this shunting effect the current dies out sooner in the gaps, *GM*, than it otherwise would. In the same manner, but to a less degree, the high resistance, *H*, draws the dynamic current from the gaps, *GH*. This current now being limited by the high resistance, the arc is easily extinguished at the end of the first one-half cycle of the generator wave.

"V" UNIT FOR MULTIGAP ARRESTERS.

The High-voltage Multigap Arrester is made up of "V" units, each unit consisting of gaps between knurled cylinders, and connected together at their ends by short metal strips. The base is of porcelain, which thoroughly insulates each cylinder, and insures the proper functioning of the multigaps.

CYLINDERS.

The cylinders are made of an improved alloy that contains metal of low boiling point which gives the rectifying effect, and metals of high boiling point which cannot vaporize in the presence of the one of low boiling point. The cylinders are heavily knurled. As the arc plays on the point of a knurl it gradually burns back and when the metal of low boiling temperature is used up, the gap is increased at that particular point. The knurling therefore, insures longer life to the cylinder, by forcing successive arcs to shift to a new point. When worn along the entire face, the cylinder should be slightly turned.

RESISTANCE RODS.

The low resistance section of the graded shunt is composed of rods of a new metallic alloy. These rods have large current-carrying capacity, and practically zero temperature coefficient up to red heat.

The medium and high resistance rods are of the same standard composition previously used. The contacts are metal caps shrunk on the ends; the resistances are per-

manent in value and the inductance is reduced to a minimum. The rods are designed with a large factor of safety, and have sufficient heat absorbing capacity to take the dynamic energy following transitory lightning discharges. They are glazed to prevent absorption of moisture, and surface arcing.

DIFFERENCE BETWEEN ARRESTER FOR GROUNDED Y AND NON-GROUNDED NEUTRAL SYSTEMS.

The connection for a three-phase arrester, 33,000 volts between lines, are shown in the illustrations (Figs. 210 and 211). One illustration (Fig. 210) shows the design for a thoroughly grounded Y system and the other for a non-grounded neutral system. The latter (Fig. 211) includes delta, ungrounded Y, and Y systems grounded through a high resistance.

The difference in design lies in the use of a fourth arrester leg between the multiplex connection and ground, on ungrounded systems. The reason for introducing the fourth leg is evident. The arrester is designed to have two legs between line and line. If one line became accidentally grounded, the full line potential would be thrown across one leg, if the fourth or ground leg were not present. On a Y system with a grounded neutral, the accidentally grounded phase causes a short circuit of the phase, and the arrester is relieved of the strain by the tripping of the circuit breaker. Briefly stated, the fourth or ground leg of the arrester is used when, for any reason, the system could be operated, even for a short time, with one phase grounded.

MULTIPLEX CONNECTION.

The multiplex connection consists of a common connection between the phase legs of the arrester above the earth connection, and provides an arrester better

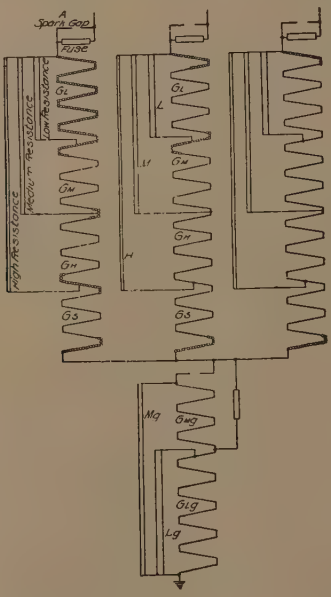


Fig. 211. Connections for 33,000-volt Delta or Ungrounded Y Systems.

adapted to relieve high potential surges between lines than would otherwise be possible. Its use also economizes greatly in space and material for delta and partially grounded or non-grounded Y systems.

FUSE AUXILIARIES.

The practice of introducing an auxiliary adjustable gap between each line wire and its corresponding leg of the arrester has been discarded in the new design with marked increase in the *sensitiveness* of the arrester. As the gap is necessary, under certain abnormal conditions, it is left on the arrester, but short circuited by a fuse so that it comes into service only when the fuse blows on account of an arc between phase and ground, or some

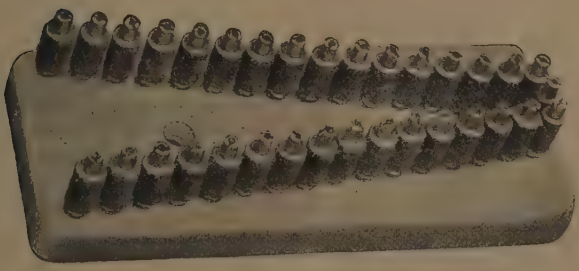


Fig. 212. "V" Unit of Multigap Lightning Arresters.

similar extremely severe continued strain. The sensitiveness is also greatly increased by the addition of a similar shunting fuse around the adjustable gap in the ground leg of the arrester. The ground leg is necessary only when there is an accidental ground of a phase and, ordinarily the increased sensitiveness is maintained continually.

LOCATION—SPACING AND SETTING OF ADJUSTABLE GAP.

Ample wall space should be provided and plenty of room in front should be left for the operator. The arresters should be placed as near as possible to where the lines enter the building. The following minimum separation distances have proved entirely satisfactory.

TABLE GIVING PROPER SPACE BETWEEN LIGHTNING ARRESTERS AND SETTING OF ADJUSTABLE GAP.

Max. Volts	Distance in Inches Between Live Parts of Adjacent Phases	Minimum Distance Between Centers (See Note)	Inches of Gap
7,600	8″	28″	1/4
12,250	8″	28″	3/8
13,500	8″	33″	3/8
17,000	10″	35″	3/8
22,000	12″	37″	1/2
27,000	18″	48″	1/2
32,000	22″	52″	5/8
37,000	26″	56″	3/4

NOTE—If barriers are used the width of barriers should be added to distances given.

It is advisable to locate arresters in a dry place, and before assembling them the wooden supports, insulators, etc., should be thoroughly dried of all moisture which may have collected during transportation.

The adjustable spark gap on these arresters is shunted by a fuse. This fuse blows under certain conditions and cuts in the added protection of the gap. The settings of this gap for the various arresters should be as already explained.

VOLTAGE RANGE OF ARRESTERS.

Lightning arresters of the form described have been designed for voltages from 5,700 to 37,000. For lower voltages, down to 300 volts, alternating current, the arresters are of slightly different design, having only

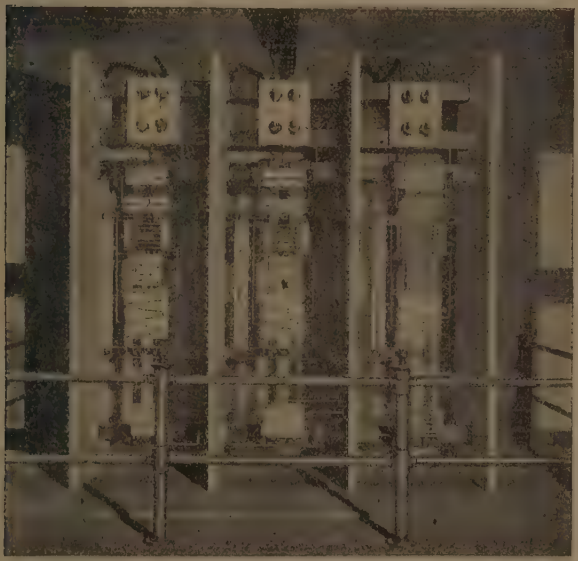


Fig. 213. Installation of a 12,000-volt, Three-Phase, Multigap Lightning Arrester in the Garfield Park Sub-Station of the West Chicago Park Commission.

two resistance rods. For 300 volts and less no resistance is necessary, as the voltage is so low that the arc cannot hold. These arresters, therefore, consist simply of spark gaps.

LOW VOLTAGE ARRESTERS—FORMS F1 AND F2. 300 TO 5,700 VOLTS.

The 2,200-volt (Figs. 214 and 217) arrester consists of one unit having fourteen cylinders, nine of which are shunted by a low resistance and eleven by a high resistance. As in the case of the high voltage arresters, the grading of resistance provides *selective paths* for dis-

Fig. 214. Form F1, 2,200-volt Multigap Arrester for Stations.

charges. Its action and advantages are therefore similar to those of the high-voltage arrester. Accumulated static charges pass off across the high resistance, and two gaps. High frequency discharges pass across all the gaps; discharges of moderate frequency across the low resistance, and four gaps. The low resistance is so proportioned to the number of shunted gaps that the high frequency dis-

charge across these gaps is not followed by the dynamic current; the dynamic shunting at once to the low resistance. The discharge takes place over all the gaps, but the arcs between the gaps shunted by the low resistances are very small compared with the bright arcs between the last four gaps. The static discharge passes through all the gaps, while the half wave of dynamic current following the static is shunted part of the way by the resistance.

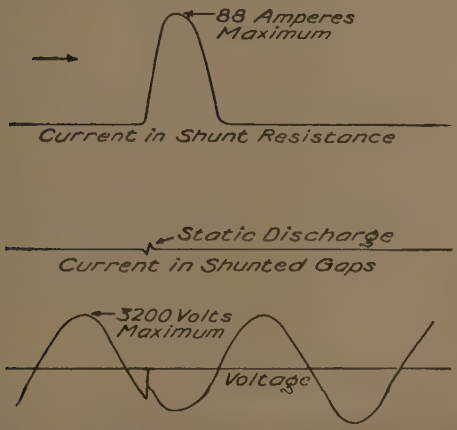


Fig. 215. Oscillograph Curves Showing Lightning Arrester Action.

An oscillogram of this phenomenon is shown in Fig. 215. The only current in the shunted gaps is the current of static discharge. It should be noted, however, that the current shown is not a measure of the true current, as the oscillograph cannot respond to currents of such high frequency.

This arrester is designed to operate across 2,200 volts. It is used, however, from each line to ground, giving, thus connected, sufficient protection and being always able to handle a discharge when one line is grounded. It is built to be used single-pole, but by placing two or three in the same box, becomes double-pole or triple-pole.

Fig. 216. Form F2, 3,000-volt Multigap Arrester for Stations.

The 1,000-volt arrester is the same in design, but has only one gap between the high resistance rod and line.

The 3,000-volt arrester (see Fig. 216) is based on the same general principle as the 2,200-volt arrester, differing from it mainly in having two additional gaps to take care of the higher voltage.

The 2,200-volt arrester (Fig. 217) is used in various combinations to form arresters of higher voltage.

LOW-VOLTAGE LIGHTNING ARRESTERS. 300 VOLTS OR LESS.

For low-voltage, alternating-current circuits up to 300 volts the lightning arrester shown in Fig. 218 is used. This type meets the requirements for the protection of

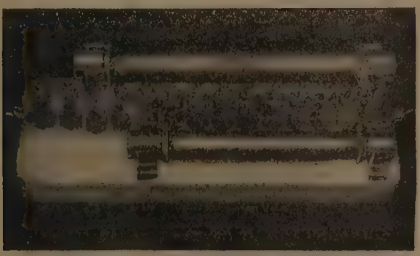


Fig. 217. 2,200-volt, Form F1, Lightning Arrester, Discharging and Shunting the Dynamic Current.

low voltage circuits such as transformer secondaries, motors, series arc lamps, etc. These arresters are made in single, double and triple-pole units.

PROTECTION OF MIXED OVERHEAD, AND CABLE SYSTEMS.

It is frequently necessary, and desirable for circuits to dip underground when passing through cities, under rivers, etc., and in these cases some form of metal covered cable is generally used. Resonance invariably pro-

duces high potentials at the junction of overhead, and underground lines, and these potentials are often of sufficient value to break down the insulation of the cables, and also the insulation of apparatus installed on the system.

Whenever lines contain both inductance, and capacity in appreciable quantities, high voltages, which endanger the insulation of the whole system, and which it is impossible to detect on ordinary switchboard instruments may exist. Abnormal voltages are therefore often found in circuits containing a combination of underground, and overhead circuits and in underground transmission lines.

Fig. 218. Single-Pole Arrester.

CONSTANT CURRENT ARRESTERS.

For constant current lighting circuits, horn arresters with resistances are recommended. It is advisable to place these arresters in the station on each outgoing line. When cables are used, the arrester should be placed on the pole where the cable joins the overhead wires. The accompanying illustration (Fig. 220) shows the appearance of a horn lightning arrester.

DISCONNECTING SWITCHES.

Lightning arresters with disconnecting switches are desirable in order that they may be disconnected from the line for proper inspection, adjustment, cleaning, etc., without opening the line circuit.

Fig. 219. Double-Pole and Triple-Pole 300-volt Arresters.

The disconnecting switches, except the 2,500-volt switches, are of the post insulator type. The 2,500-volt switches are single-blade, front connected, and are mounted directly on marble bases. The post insulator switches are arranged for mounting on flat surfaces.

CHOKE COILS.

The proper selection of choke coils is an important feature of lightning protection. Choke coils should be used with lightning arresters except, when the arresters are used to protect cable systems.

Fig. 220. Horn Arrester for Constant Current Circuits.

Three types of choke coils are shown in Figures 222 and 223. The 4,600-volt coil is made of insulated wire, wound on wooden core supported by iron feet. The 6,000-volt coil is made of insulated wire and is mounted on marble base. For voltages above 6,000 the "hour glass" type with air insulated turns is used. With this type the coil is mounted on a wooden, slate or marble base.

The "hour glass" type has the following advantages on high voltages.

1. Should there be any arcing between adjacent turns, the coils will reinsulate themselves after the discharge.

2. They are mechanically strong, and sagging is prevented by tapering the coils toward the center turns.

3. The insulating supports can best be designed for the strains that they have to withstand.

In providing lightning arresters the following points should be considered:

Fig. 221. Post Type Insulator Disconnecting Switch.

1. What is the normal line to line voltage?

2. How many sets of transmission lines are there?

3. Is the system single-phase, two-phase, or three-phase; or three-phase, four wire?

4. Is the system delta connected; *Y* connected, neutral non-grounded; or *Y* connected, neutral grounded?

5. If single-phase, is the neutral grounded?

6. Are switches to be furnished with the arrester?

7. If so, are they to be double-blade or single-blade?

8. If double-blade switches are required, state the current-carrying capacity of the line switch.

9. Are choke coils to be furnished? If so, state their ampere capacities and the number desired.

10. The number of switch hooks to be furnished.

11. If the line is partly overhead, and partly underground, submit a rough sketch that shows where the underground portion is located with reference to the stations and the remainder of the line.

DIRECT CURRENT LIGHTNING ARRESTERS.

The Type M Form D-2 arrester (Fig. 224) has been the standard for direct current circuits for several years, and is furnished for lighting and power circuits of from 60 to 375 volts, and for railway and power circuits of from 250 to 1,800 volts.

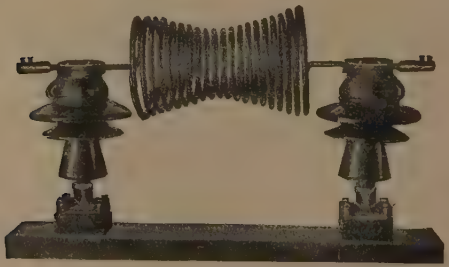


Fig. 222. Hour Glass Type—Choke Coil 15,000-35,000 Volts.

The present form of arrester is somewhat longer and narrower than the earlier types, and the spark gap, and non-inductive resistance are in a straight line, thus forming a direct path for the discharge, and reducing to a minimum the possibility of short circuit in the box in case of excessively heavy lightning discharges. One of

the valuable features of the MD-2 arrester is the fact that all parts can be readily inspected on removing the cover of the porcelain enclosing box (Fig. 225) and a glance will show if the arrester is in proper condition for the next storm. The gap is surrounded by a strong electro-magnet, which immediately blows out the dynamic arc through the chute after the lightning discharge has passed.

The gaps on arresters up to 850 volts are adjusted to .025 inch, and on higher voltages to .094 inch. These arrangements have been found to afford excellent protection to the insulation of the equipments, due to the low breakdown points.

6,000 Volts. 4,600 Volts.
Fig. 223. Low Voltage Choke Coils.

The spark gap terminals are threaded, and attached to the lid of the box, thus affording a ready method of adjustment, positive grip on the terminals, and easy access for examination.

GROUND CONNECTIONS.

In all lightning arrester installations it is of utmost importance to make perfect ground connections, as a large majority of lightning arrester troubles can be traced to the lack of this precaution. It has been cus-

tomary to ground a lightning arrester by means of a large metal plate buried in a bed of charcoal, at a depth of six or eight feet in the earth.

A more satisfactory method of making a ground is to drive a number of 1 in. iron pipes six or eight feet into the earth at several points about the station, connecting all these pipes together by means of copper wire or preferably copper strip. A quantity of salt should be placed around each pipe at the surface of the ground and

Fig. 224. Direct Current Arrester, Type M, Form D-2.

the ground thoroughly moistened with water. It is advisable to connect the pipes to the iron frame work of the station, and also to any water mains, metal flumes, or trolley rails that are available.

For the station of ordinary size the following recommendation is made. Place three earth-pipes equally spaced near each outside wall, making twelve altogether, and place three extra pipes spaced about 6 feet apart at a point nearest the arrester.

When plates are placed in streams of running water,

it is much better for them to be buried in the mud along the bank, than to lie in the stream. Streams with rocky bottoms are to be avoided except as a last resort.

Whenever plates are placed at any distance from the arrester it is advisable to drive a pipe in the earth directly beneath the arrester, thus making the ground

Fig. 225. Direct Current Lightning Arrester—Interior.

connections as short as possible. Earth plates at a distance cannot be depended upon. Long ground wires in a station cannot be depended upon, unless a lead is carried to the multiple pipe-earths described above.

In view of the fact that it is advisable to occasionally examine the ground connections to see that they are in proper condition, it is desirable to lay out the exact plans

of the location of the ground plates, ground wires, or pipes, with a brief description of them, so that at any time the data may be referred to.

From time to time the resistance of the ground connections should be measured to determine their condition. This is very easily done when pipe grounds are installed, as the resistance of one pipe can be accurately determined, when three or more pipes are used. The resistance of a single pipe ground in good condition has an average value of about 15 ohms. A simple and satisfactory method of keeping account of the condition of the earth connections is to divide the pipe-earths into two groups, and connect each group to the 110-volt lighting circuit, with an ammeter in series. If there is a flow of about 20 amperes the conditions are satisfactory, provided the pipe-earths are properly distributed around the station.

LIGHTNING ARRESTERS—ALTERNATING CURRENT GRADED SHUNT RESISTANCE FOR LOW VOLTAGE CIRCUITS—UP TO 5700 VOLTS.

Voltage of System Line to Line.	Class of System.	CAT. NO. ARRESTER.	
		Line.	Station.
Up to 301	3-phase △ or ungrounded Y	3413 single pole 38126 double pole 38127 triple pole	
301-1200	3-phase △ or ungrounded Y	46710 single pole	46711 single pole
1201-2300	3-phase △ or ungrounded Y	46712 single pole 46714 double pole 46716 triple pole	45477 single pole 46713 double pole 46715 triple pole
2301-3000	3-phase △ or ungrounded Y	75947 single pole	75946 single pole
3001-4150	3-phase △ or ungrounded Y	46981 single pole	46980 single pole 46753 triple pole
4151-5700	3-phase △ or ungrounded Y	75488 triple pole	75242 triple pole
Up to 301	3-phase grounded Y	3413 single pole 38126 double pole 38127 triple pole	
301-2000	3-phase grounded Y	46710 single pole	46711 single pole
2001-3500	3-phase grounded Y	46712 single pole 46714 double pole 46716 triple pole	45477 single pole 46713 double pole 46715 triple pole
3501-4500	3-phase grounded Y	75947 single pole	75946 single pole
4501-5700	3-phase grounded Y	46981 single pole	46980 single pole 46753 triple pole

LIGHTNING ARRESTERS—UP TO 5700 VOLTS—CONTINUED.

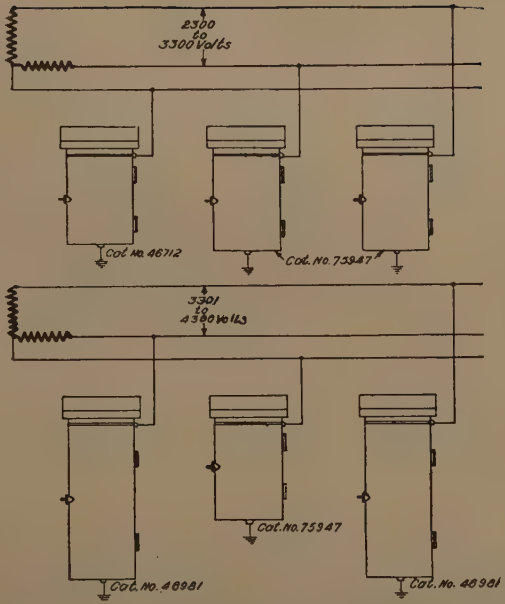
Voltage of System Line to Line.	Class of System.	CAT. NO. ARRESTERS.	
		Line.	Station.
Up to 301	Single phase ungrounded	3413 single pole 38126 double pole	
301-1200	Single phase ungrounded	46710 single pole	46711 single pole
1201-2300	Single phase ungrounded	46712 single pole 46714 double pole	45477 single pole 46713 double pole
2301-3000	Single phase ungrounded	75947 single pole	75946 single pole
3001-4150	Single phase ungrounded	46981 single pole	46980 single pole
4151-5700	Single phase ungrounded	76020 double pole	76010 double pole
Up to 301	Single phase grounded neutral	3413 single pole 38126 double pole	
301-2000	Single phase grounded neutral	46710 single pole	46711 single pole
2001-3500	Single phase grounded neutral	46712 single pole 46714 double pole	45477 single pole 46713 double pole
3501-4500	Single phase grounded neutral	75947 single pole	75946 single pole
4501-5700	Single phase grounded neutral	46981 single pole	46980 single pole
1200-2000	Single phase, one line grounded	46712 single pole	45477 single pole
2001-2600	Single phase, one line grounded	75947 single pole	75946 single pole
2601-3500	Single phase, one line grounded	46981 single pole	46980 single pole
*2300-*3300	Quarter phase, three wire		
*3301-*4300	Quarter phase, three wire		

Quarter phase, four wire—treat as single phase ungrounded.

*Voltage across outside wires.

Cat. No.	Description.	Approx. Shipping Weight in Lbs.
3413*†	S.P. Form D, Line Arrester in iron box - - -	6
38126*	D.P. Form D, Line Arrester in iron box - - -	8.5
38127*	T.P. Form D, Line Arrester in iron box - - -	11
45477	S.P. Form F1, Station Arrester - - - - -	7.5
46710	S.P. Form F1, Line Arrester in wooden box - - -	15
46711	S.P. Form F1, Station Arrester - - - - -	7.5
46712	S.P. Form F1, Line Arrester in wooden box - - -	15
46713	D.P. Form F1, Station Arrester - - - - -	15
46714	D.P. Form F1, Line Arrester in wooden box - - -	28
46715	T.P. Form F1, Station Arrester - - - - -	22
46716	T.P. Form F1, Line Arrester in wooden box - - -	42
46753	T.P. Form F1, Station Arrester - - - - -	28
46980	S.P. Form F1, Station Arrester - - - - -	15
46981	S.P. Form F1, Line Arrester in wooden box - - -	24
75242	T.P. Form F1, Station Arrester - - - - -	70
75488	T.P. Form F1, Line Arrester in wooden box - - -	96
75946	S.P. Form F2, Station Arrester - - - - -	10
75947	S.P. Form F2, Line Arrester in wooden box - - -	20
76010	D.P. Form F1, Station Arrester - - - - -	71
76020	D.P. Form F1, Line Arrester in wooden box - - -	95

*Not of graded shunt resistance type. For Transformer secondaries. †Also for individual arc lamp.

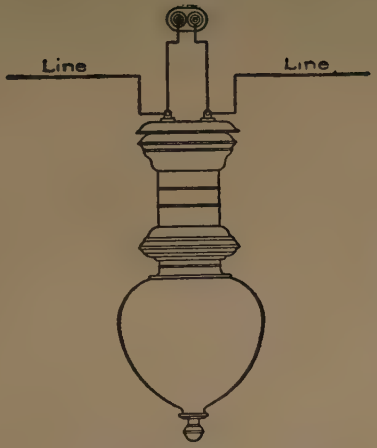


Connections of Type GE Forms F1 and F2 Lightning Arresters for Two-phase Three-wire Alternating Current Circuits.

Arresters shown in opposite diagram are for line service.

For station service use corresponding single-pole station type as follows:

LINE	STATION
Cat. No. 46712	Cat. No. 45477
Cat. No. 46981	Cat. No. 46980
Cat. No. 75947	Cat. No. 75946



Low-voltage Lightning Arrester
Cat. No. 3413

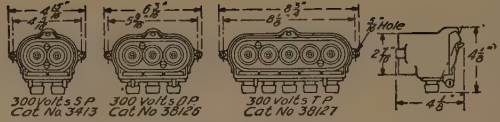
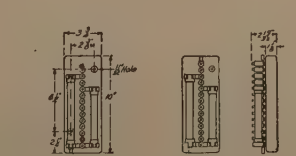


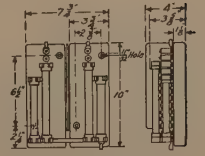
Fig. 226.

Dimensions of Low-Voltage Alternating Current Lightning Arresters

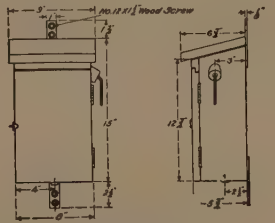


S.P. STATION ARRESTER
CAT. NO. 46711

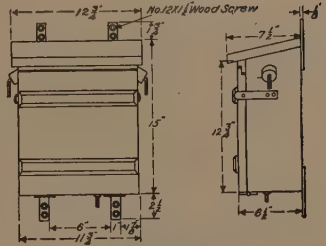
S.P. STATION ARRESTER
CAT. NO. 45477



D.P. STATION ARRESTER
CAT NO. 46713



S.P. LINE ARRESTERS
CAT. NOS. 46710 AND 46712



D.P. LINE ARRESTER
CAT. NO. 46714

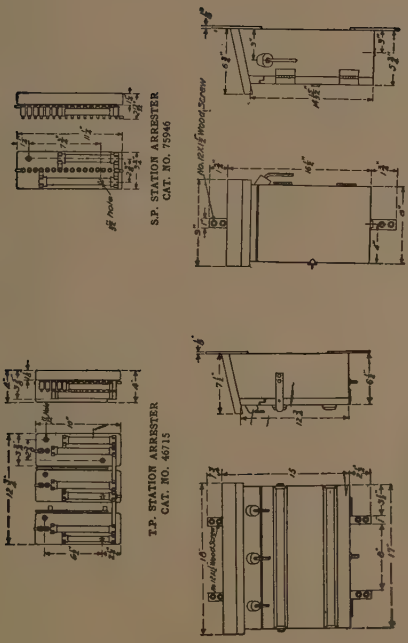
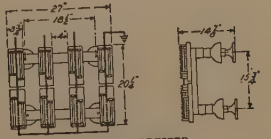
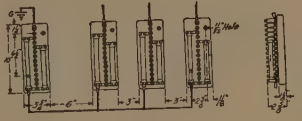

S.P. STATION ARRESTER
CAT. NO. 75946
S.P. LINE ARRESTER
CAT. NO. 75947
T.P. STATION ARRESTER
CAT. NO. 46715
T.P. LINE ARRESTER
CAT. NO. 46716

Fig. 227.

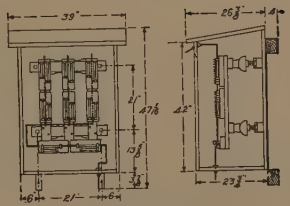
Dimensions of Low Voltage Alternating Current Lightning Arresters



STATION ARRESTER
CAT. NO. 75242



CAT. NO. 46753



LINE ARRESTER
CAT. NO. 75488

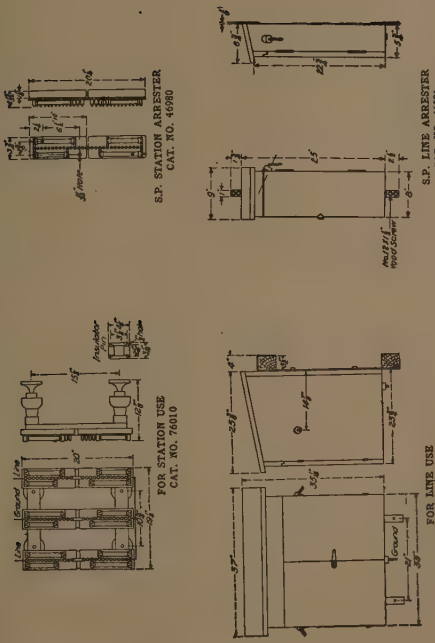

S.P. STATION ARRESTER
CAT. NO. 46980
S.P. LINE ARRESTER
CAT. NO. 46981
FOR STATION USE
CAT. NO. 76010
FOR LINE USE
CAT. NO. 76020

Fig. 228.

Alternating Current Lightning Arresters with Graded Shunt Resistance

The Following Cat. Nos. Do Not Include Disconnecting Switches

THREE-PHASE FOR "DELTA" OR UNGROUNDED "Y" CIRCUITS			THREE-PHASE FOR GROUNDED "Y" CIRCUITS		
Cat. No.	Min. and Max. Voltage on which Arresters should be Installed	Approx. Shipping Weight in Lb.	Cat. No.	Min. and Max. Voltage on which Arresters should be Installed	Approx. Shipping Weight in Lb.
46991	5700- 7600	353	46992	5700- 7600	325
46993	7601-12250	465	46994	7601-12250	420
46995	12251-13500	550	46996	12251-13500	500
46997	13501-17000	650	46998	13501-17000	575
46999	17001-22000	805	47000	17001-22000	715
47001	22001-27000	980	47002	22001-27000	870
47003	27001-32000	1245	47004	27001-32000	1115
47005	32001-37000	1430	47006	32001-37000	1320

Dimensions of Alternating Current Graded Shunt Resistance Multigap Lightning Arresters for Three-phase Delta or Ungrounded "Y" Circuits.

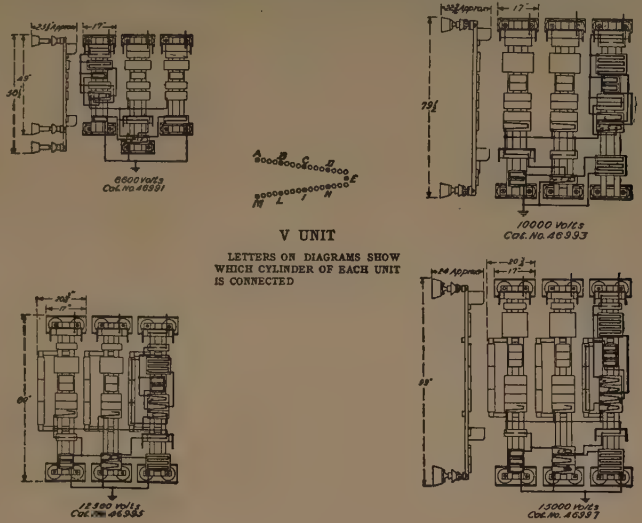
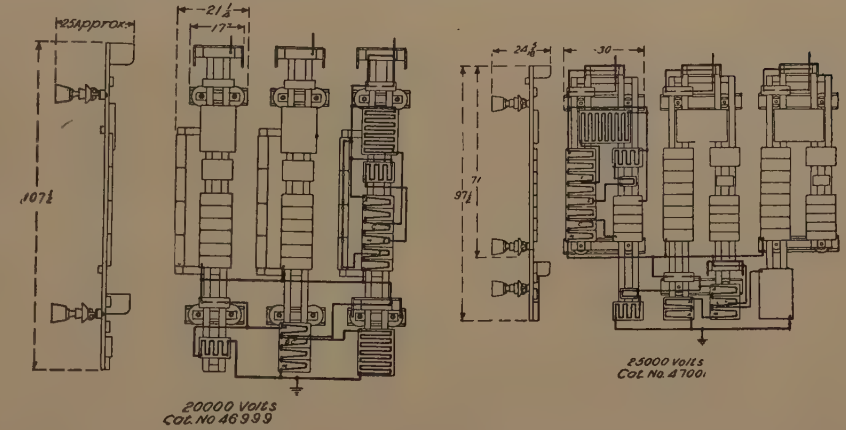


Fig. 229.

Dimensions of Alternating Current Graded Shunt Resistance Multigap Lightning Arresters for Three-phase Delta or Ungrounded "Y" Circuits—Continued



V UNIT

LETTERS ON DIAGRAMS SHOW WHICH CYLINDER OF EACH UNIT IS CONNECTED

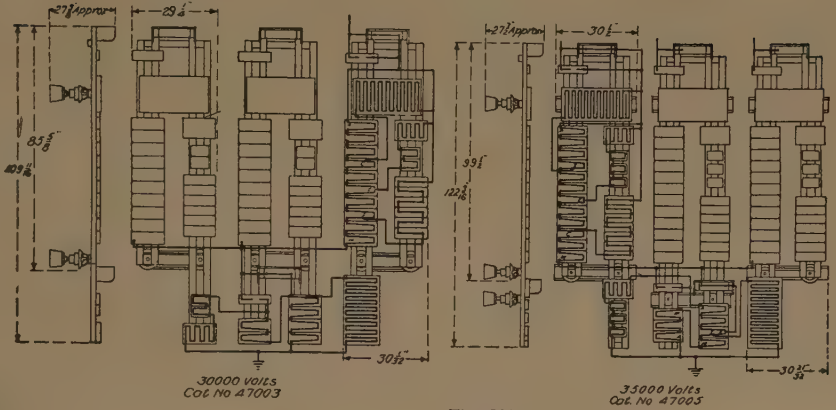
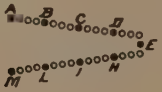


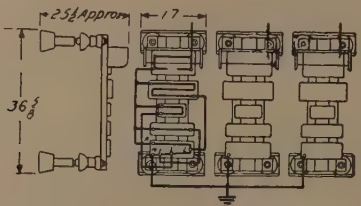
Fig. 230.

Dimensions of Alternating Current Graded Shunt Resistance Multigap Lightning Arresters for Three-phase Grounded "Y" Circuits

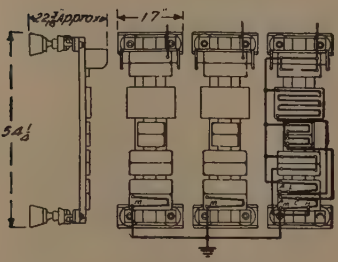


V UNIT

Letters on Diagrams Show which Cylinder of Each Unit is Connected



6600 Volts
Col No 46992



10000 Volts
Col. No. 46994

Fig. 231.

Dimensions of Alternating Current Graded Shunt Resistance Multigap Lightning Arresters for Three-phase Grounded "Y" Circuits—Continued

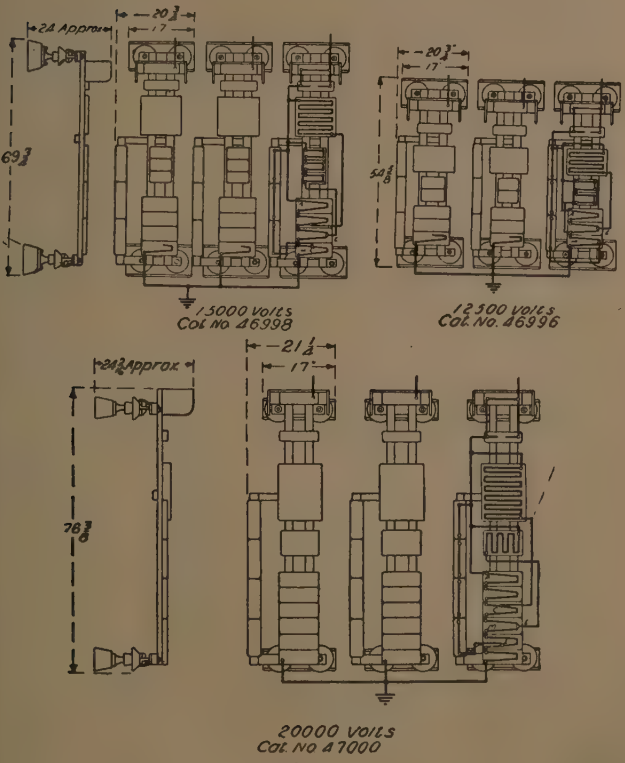
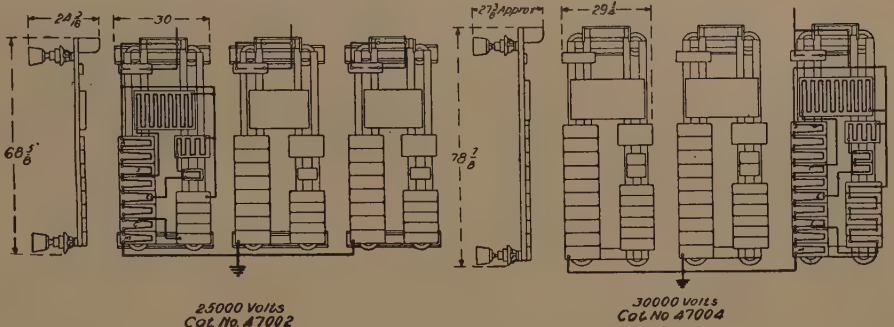
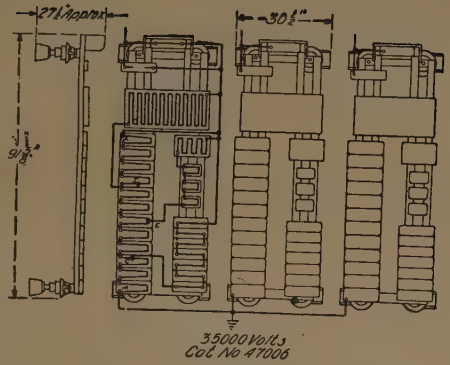


Fig. 231.

Dimensions of Alternating Current Graded Shunt Resistance Multigap Lightning Arresters for Three-phase Grounded "Y" Circuits—Continued



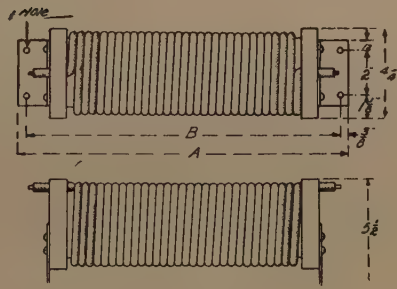


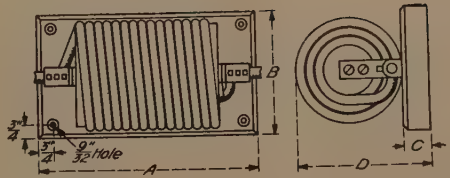
V UNIT

Letters on Diagrams Show which Cylinder of each Unit is Connected

Fig. 232.

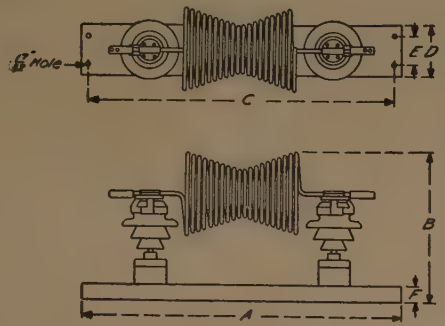
Choke Coils for Use with Alternating Current Lightning Arresters





Cat. No.	Max. Volts	Amp.	A	B	Cat. No.	Max. Volts	Amp.	A	B	C	D
76339	4600	25	15 3/8	14 5/8	25401	6000	25	10 1/2	5 1/2	1 1/4	5 13/16
76340	4600	50	17 5/8	16 7/8	3416	6000	100	12 1/2	7	1 1/2	7 3/4
					36882	6000	200	12 1/2	7	1 1/2	7

Dimensions of Choke Coils, Hour Glass Type—6000 to 35000 Volts



Cat. No.	Base	Max. Volts	Amp.	A	B	C	D	E	F
46930	Wood	15000	200	38½	16⅝	36½	4	2	2
46931	Slate	15000	200	36	15⅝	34	8	6	1⅛
46932	Marble	15000	200	36	15⅝	34	8	6	1⅛
46933	Wood	25000	200	38½	18 5/16	36½	4	2	2
46934	Slate	25000	200	36	17 5/16	34	8	6	1⅛
46935	Marble	25000	200	36	17 5/16	34	8	6	1⅛
46936	Wood	35000	200	38½	21⅞	36½	6	4	2
46937	Slate	35000	200	36	20⅞	34	9	7	1⅜
46938	Marble	35000	200	36	20⅞	34	9	7	1⅜

Fig. 233.

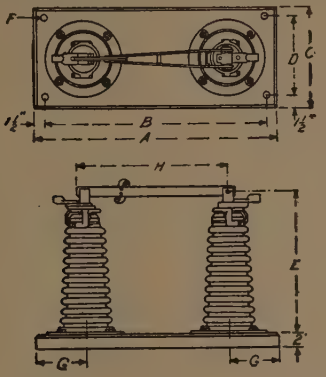
Disconnecting Switches for Use with Alternating Current Lightning Arresters

Cat. No.	Voltage	A	B	C	D	E	F	G	H
76433	15000	18	15	9	6	$9\frac{23}{32}$	$\frac{9}{16}$	$4\frac{1}{2}$	$11\frac{1}{8}$
76666	25000	24	21	12	9	$12\frac{1}{4}$	$\frac{11}{16}$	6	$14\frac{1}{4}$
76668	35000	30	27	13	10	15	$\frac{11}{16}$	$6\frac{1}{2}$	$19\frac{1}{4}$
76670	45000	34	31	14	11	$19\frac{1}{8}$	$\frac{11}{16}$	7	$21\frac{7}{32}$
76672	70000	44	41	16	13	$23\frac{1}{4}$	$\frac{11}{16}$	8	$29\frac{7}{32}$
76674	90000	51	38	16	13	$29\frac{3}{16}$	$\frac{11}{16}$	8	$37\frac{1}{16}$
76675	110000	60	57	18	15	$36\frac{1}{4}$	$\frac{11}{16}$	9	$44\frac{1}{16}$

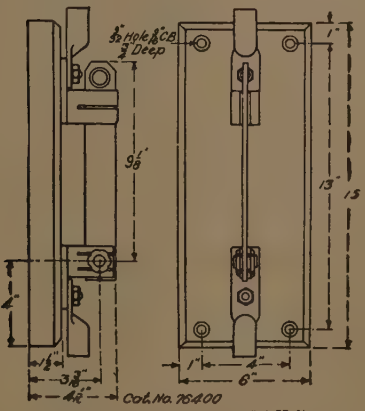
Hooks and Handles for Use with Disconnecting Switches

Cat. No.	Max. Volts	Length in Feet
65849	15000	4
65850	45000	8
65851	70000	12
65852	110000	16

Disconnecting Switches for Use with Alternating Current Lightning Arresters—Continued



Disconnecting Switch for 15000 to 45000 Volts



Disconnecting Switch for 2500 Volts

Fig. 233—Continued

FOR USE ON SECONDARIES OF CONSTANT CURRENT TRANSFORMERS FOR ARC LIGHTING SYSTEMS.

Cat. No.	Rating of Transformers.	No. Required.
47558	25 light	1
47559	35 light	1
47560	50 light single-circuit	1
47561	75 light single-circuit	1
47562	100 light single-circuit	1
47577	100 light multi-circuit	2

FOR USE ON SECONDARIES OF MERCURY ARC RECTIFIER SYSTEMS.†

Cat. No.	Lights Capacity	Volts
58959	12	1100
58960	25	2300
58961	50	4600
58962	75	6900
58961	100*	4600

*Multi-circuit—two arresters required.

†Arresters Cat. Nos. 58959 to 58962 inclusive are also suitable for use on other D. C. Series Arc Systems.

Barriers for use with Horn Type Station Arrester, Cat. No. 47564.

RECOMMENDATIONS FOR ADJUSTING THE GAP OF HORN ARRESTERS.

Voltage of Circuit	Gap in Inches G	Voltage of Circuit	Gap in Inches G
1100	1/8	4600	1/4
1500	1/8	6900	3/8
2300	1/8	9200	1/2
3200	3/16		

HORN LIGHTNING ARRESTERS FOR CONSTANT CURRENT INCANDESCENT CIRCUITS.

Cat. No. Arrester	Kw. Capacity of Trans.	Secondary Amperes
47558	3.8	1 3/4
47563	3.8	3 1/2
47563	3.8	4
47563	3.8	5 1/2
47563	3.8	6.6
47563	3.8	7.5
47560	7.65	1.75
47558	7.65	3.5
47558	7.65	4
47563	7.65	5.5
47563	7.65	6.6
47563	7.65	7.5
47562	15.7	1.75
47560	15.7	3.5
47560	15.7	4
47559	15.7	5.5
47558	15.7	6.6
47558	15.7	7.5
47561	21.5	3.5
47561	21.5	4
47560	21.5	5.5
47559	21.5	6.6
47559	21.5	7.5
47562	31.0	3.5
47562	31.0	4
47561	31.0	5.5
47560	31.0	6 6
47560	31.0	7.5

DIMENSIONS AND WEIGHTS OF HORN LIGHTNING ARRESTERS.

Cat. No.		Approx. Shipping Wt. in Lb.	Dimensions in Inches		
Direct Current	Alternating Current		A	B	C
	47558	30	24	$8\frac{1}{4}$	$3\frac{3}{4}$
58960	47559	95	$23\frac{7}{8}$	$28\frac{7}{8}$	$8\frac{1}{2}$
	47560	110	$23\frac{7}{8}$	$29\frac{5}{8}$	$8\frac{1}{2}$
58961	47561	110	$23\frac{7}{8}$	28	$8\frac{1}{2}$
58962	47562	165	$23\frac{7}{8}$	32	17
58959	47563	25	24	$13\frac{9}{16}$	$3\frac{3}{4}$
	47577	175	$23\frac{7}{8}$	$29\frac{5}{8}$	17

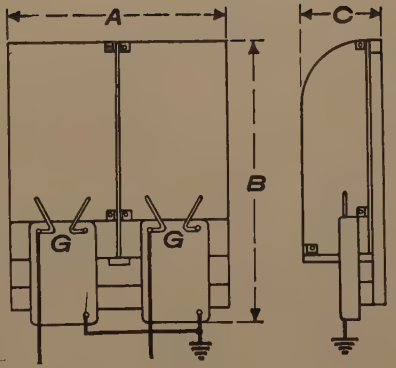


Fig. 234.

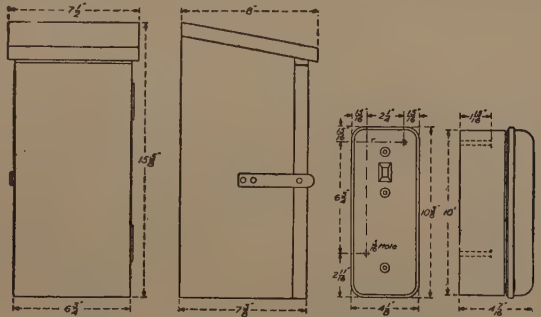
Lightning Arresters for Direct Current Circuits

Type M Form D-2

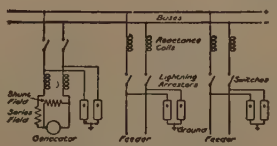
Cat. No.	Description	Voltage	Approx. Shipping Weight in Lb.
33619	For station use	60 to 200	15
33620	In wooden box for line use .	60 to 200	25
33867	Extra resistance	60 to 200	..
33621	For station use	125 to 375	15
33622	In wooden box for line use .	125 to 375	25
33868	Extra resistance	125 to 375	..
33623	For station use	250 to 850	15
33625	In wooden box for line use .	250 to 850	25
33869	Extra resistance	250 to 850	..
46145†	For station use	600 to 1800	15
46146†	In wooden box for line use .	600 to 1800	25
59925	Extra resistance	600 to 1800	..

†Two required. Two arresters to be installed in series.

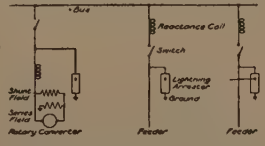
Dimensions and Connections of Lightning Arresters for Direct Current Circuits



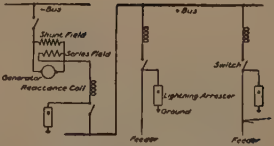
Dimensions of Type M Form D-2 Lightning Arrester



Connections for D. C. Ungrounded Circuit up to 850 Volts



Connections for D. C. Grounded Return Circuit up to 850 Volts Machine Equalizing on Negative Side



Connections for D. C. Grounded Return Circuit up to 850 Volts Machine Equalizing on Positive Side

Fig. 235.

INSTRUCTIONS FOR INSTALLING ALTERNATING CURRENT ALUMINUM LIGHTNING ARRESTERS.

ELECTRICAL CHARACTERISTICS.

The design of the aluminum arrester is based on the characteristics of a cell consisting of two aluminum plates on which has been formed a film of hydroxide of aluminum, immersed in a suitable electrolyte. This film is formed on the aluminum plates by a series of chemical and electro-chemical treatments at the factory.

Valve Action. Up to a certain critical voltage this hydroxide film has the property of insulating, or rather opposing the flow of current and is, therefore, closely analogous to a counter-electro-motive force. Up to this critical voltage only a small leakage and charging current can flow, but during any rise above this voltage the current flow through the cell is limited only by the actual resistance of the electrolyte, which is very low. The action is comparable to that of the well-known safety valve of a steam boiler by which the steam is confined until the pressure rises to a given value, at which point the valve opens and releases the excess pressure. This action of the aluminum cell is also closely analogous to that of a storage battery on direct current. Up to about two volts per cell, impressed, the storage battery, when charged, opposes an equal counter-electro-motive force, shutting off the flow of current; but for voltage above this value the current is limited only by the internal

resistance of the cell. This characteristic makes the aluminum cell ideal as a means of discharging abnormal potentials, or surges in electric circuits. It practically

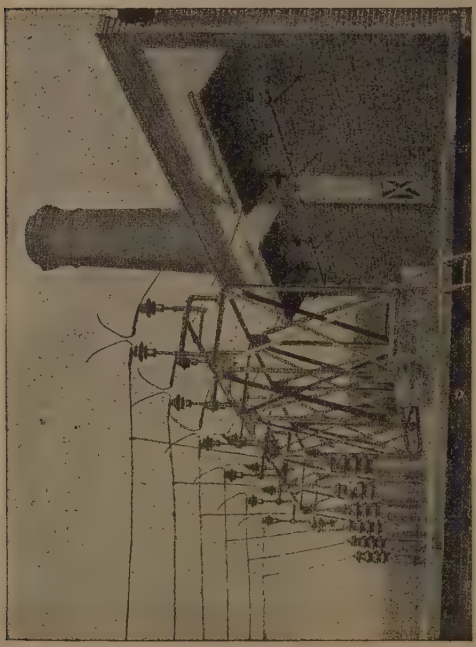


Fig. 236. Horn Gap Installation for 35,000 Volt Aluminum Lightning Arresters, Schenectady Power Co., Showing Roof Entrances to Station and Wall Entrances to Lightning Arrester Tower. One Set of Arresters Disconnected.

prevents the flow of current at operating voltages, but instantly short circuits such abnormal portions of a potential wave, or surge, as would be dangerous to the insulation of the system.

A volt-ampere-characteristic-curve of the aluminum cell on alternating current is shown in Fig. 237. The data for this curve was taken with an oscillograph. It

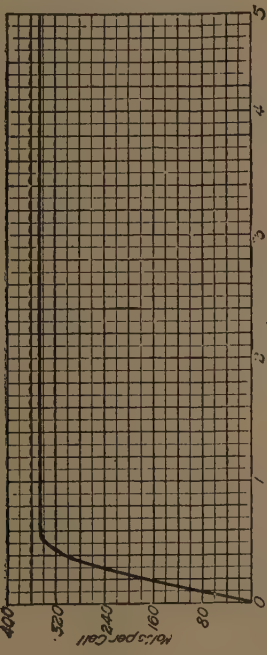


Fig. 237. Volt-Ampere Characteristic Curve of Aluminum Cell.

should be noted that the critical voltage, alternating current, is slightly above 340 volts. This cut gives the discharge rate only up to 5 amperes, in order to better illustrate the normal and critical voltage points. Above

this value the discharge rate depends almost entirely upon the internal resistance of the electrolyte. This resistance is such that at double the normal operating voltage, or 600 volts per cell, the current discharge is six hundred, to one thousand amperes for a brief time. This rate of discharge represents a quantity of electricity several times greater than the quantity liberated by an ordinary induced lightning stroke.

Condenser Action. Besides the valve action described above there is another characteristic of the cell of great importance. The thin insulating film of aluminum hydroxide between the conducting aluminum, and the conducting electrolyte acts as a dielectric and the cell, therefore, is an electstatic condenser. A condenser of this type makes an ideal path for high frequency lightning discharges. With these arresters, for instance, 10,000 cycles, which is not an unusual frequency for lightning disturbances, would discharge almost 100 amperes without any rise in voltage.

Due to this capacity, these aluminum arresters cannot be connected permanently across alternating voltage. The charging current at normal frequency (about .5 amp.) would in time heat the electrolyte. In every case, therefore, spark gaps set to arc over at slight increase of voltage, insulate the arrester from the line.

Film Dissolution. Another characteristic of the aluminum cell is the dissolution of a part of the film when the plates stand in the electrolyte, and the cell is disconnected from the circuit. The film is presumably composed of two parts; one part is hard and insoluble, and apparently acts as a skeleton to hold the more soluble part. When a cell, which has stood for some time disconnected, is reconnected to the circuit, there is

a momentary rush of current, which replaces the part of the film which has dissolved. All electrolytes dissolve the film, the extent of the dissolution depending upon

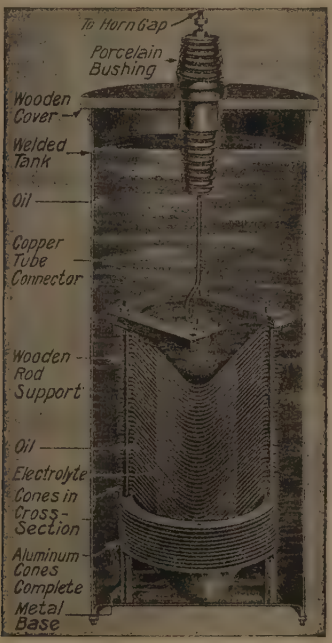


Fig. 238. Cross Section of Aluminum Lightning Arrester.

the length of time the film is in the electrolyte, the electrolyte used, and its temperature. It is necessary to charge the cells from time to time to prevent the initial rush of dynamic current causing trouble. By keeping

the films formed at all times, the initial rush of current is prevented, and the ultimate temperature rise in case of continued discharge of the arrester is minimized. The ability of the arrester to take care of discharges lasting for any considerable length of time, therefore, depends upon the condition of the arrester film. When the cells, in commercial use, are allowed to stand for not more than a day or two, the film dissolution, and initial cur-

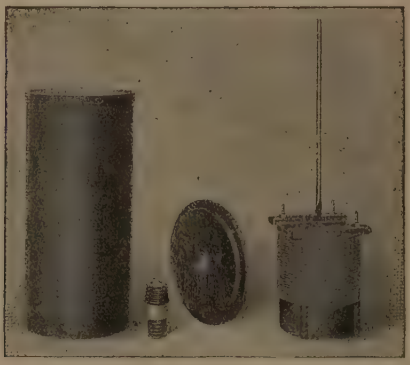


Fig. 239. Parts of One Leg of 15,000 Volt Aluminum Lightning Arrester.

rent rush is negligible. Suitable means are provided with the arresters for connecting them directly across the line. This is a very simple operation, and thus the film is kept in good condition.

In very warm climates it is sometimes advisable to take special precaution to keep the cells normally cool.

Design. The aluminum lightning arresters for alternating current circuits from 1,000 to 110,000 volts con-

sist essentially of inverted aluminum cones, placed one above the other in stacks, and insulated with a vertical spacing of about .3 inch. An electrolyte partially fills the space between adjacent cones, so forming aluminum cells connected in series. The stack of cones with the electrolyte between them is then immersed in a tank of oil. The electrolyte being heavier than the oil remains between the aluminum cones. The oil improves the insu-

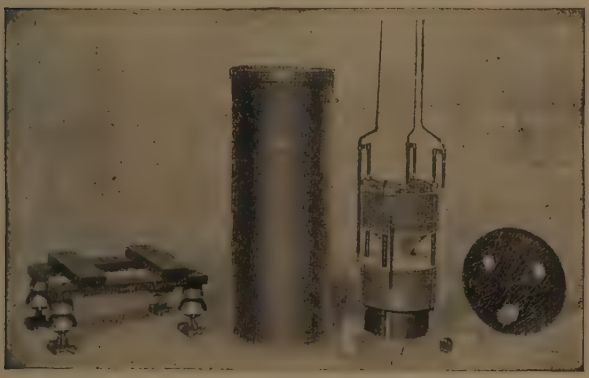


Fig. 240. Tank, Cones and Stand of 4,600 Volt Three-Phase Aluminum Lightning Arrester for Non-Grounded Neutral Systems.

lation between cones, prevents evaporation of the solution and, due to its heat absorbing capacity, enables the arresters to discharge continuously for long periods, a very valuable feature of these arresters. The tanks are of steel with welded seams.

The general arrangement of the cells is shown in Figs. 238-239-240.

Fig. 241. 60,000 Volt Horn Gap—Charging Position.

Fig. 242. 60,000 Volt Horn Gap—Disconnecting Position.

Location of Arrester. The location and arrangement of an aluminum lightning arrester installation depends greatly upon the station layout. In general, the arrester

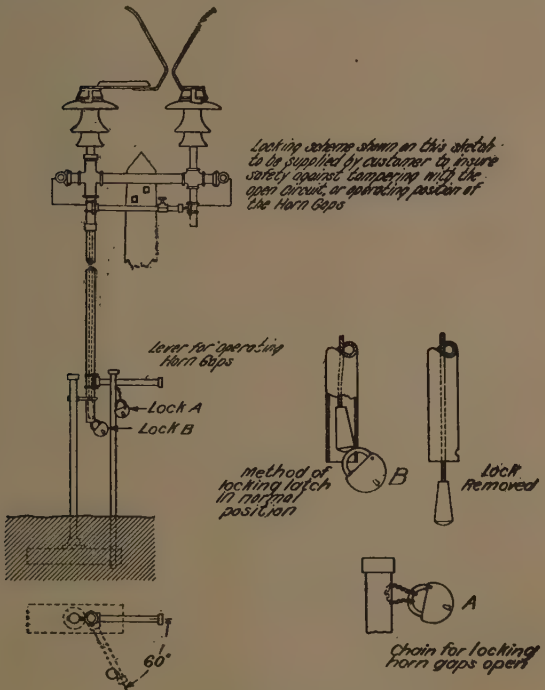

Locking scheme shown on this sketch to be supplied by customer to insure safety against tampering with the open circuit, or operating position of the Horn Gaps
Lever for operating Horn Gaps
Lock A
Lock B
Method of locking latch in normal position
B
Lock Removed
A
Chain for locking horn gaps open
60°

Fig. 243. Method of Locking Horn Gaps.

should be installed as near as possible to the apparatus or station to be protected. The ideal arrangement would be to have the tanks and horn gaps installed as a com-

Fig. 244. 6,600 Volt Aluminum Lightning Arrester for Three-Phase Non-Grounded Neutral Systems.

plete unit just inside the station. For lower voltage equipments this is feasible, as the arcing at the gaps is not severe even in abnormal cases. Above 27,000 volts, this practice is usually questionable, and it is recom-

mended that the horn gaps be installed outside the building, with leads tapping the line near its entrance to the station. The tanks, cones and transfer device should be installed inside of the station in a suitable compart-

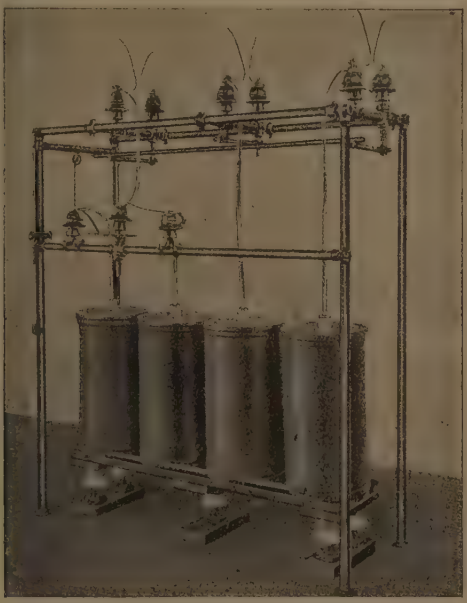


Fig. 245. 12,500 Volt Aluminum Lightning Arrester for Three-Phase Non-Grounded Neutral Systems.

ment. This requires the use of either wall or roof entrance bushings for the connecting wires. The object of placing the horn gaps outside of the station is to isolate any arc from the station apparatus.

The horn gaps for high voltage (see Figs. 241-242-243) are supported on a 2 in. pipe framework which is so designed that they can be mounted on either wooden or steel towers, or if desirable on the roof of the station,

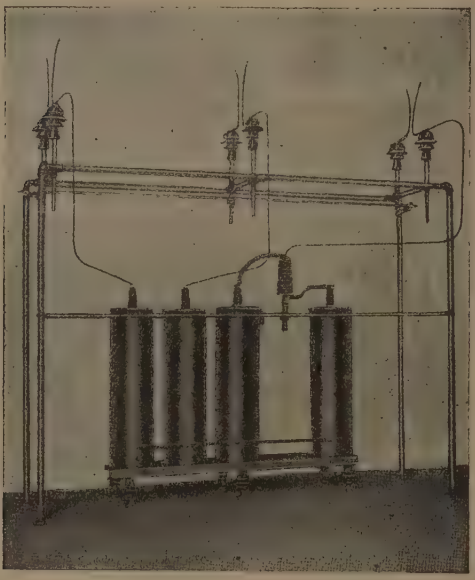


Fig. 246. Aluminum Lightning Arrester for 35,000 Volt Three-Phase Non-Grounded Neutral Circuits With Horn Gaps Mounted Indoors.

or on suitable brackets on the outside wall of the station. They should be so located that the pipe and lever, by which they are operated, can be brought down in a place

convenient for the operator, and if possible where he can observe the arcing at the horns during discharge. It is also advisable to have the transfer device, and horn gaps operated from the same place so as to reduce the work of charging to a minimum. The horn gaps for lower voltages (Figs. 244-245) are sent complete for mounting inside the station.

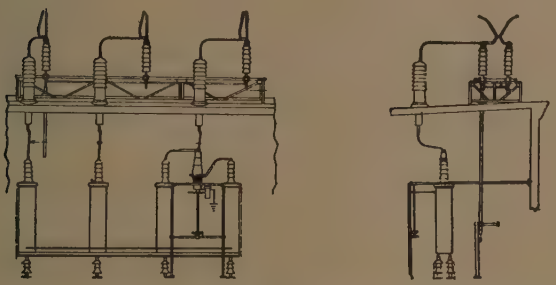


Fig. 247. Aluminum Lightning Arrester Installation for 110,000 Volt Three-Phase Non-Grounded Neutral System, Showing Horn Gaps on Roof, Roof Entrances and Tanks Inside of Station.

Wherever horn gaps are mounted inside the building sufficient clearance should be allowed over them. The exact distance to be allowed depends upon the voltage, and the nature of the material or apparatus under which the horns are installed. If there are cables, wires, buses, or any material which would be damaged by fire, considerable distance should be allowed. On the other hand, if there are only concrete and iron beams of the floor or roof, a much smaller clearance can be allowed,

Normally there is no appreciable arc at the gaps, but in abnormal cases where the film has been allowed to get out of order, the arc might be of considerable size. Where there are no buses or inflammable apparatus, the following are the minimum clearances from the tops of horns to be allowed:

Up to	7,250	volts	2 ft.
7,251 to	16,100	volts	3 ft.
16,101 to	37,900	volts	4 ft.
37,901 to	60,000	volts	6 ft.

Above 60,000 volts, the horn gaps should never be placed indoors.

In accordance with the above, standard equipments of 27,000, and below are designed as complete units to be installed inside the station, while for those above 27,000 volts the horn gaps should preferably be installed outside the station, and the tanks inside. Exception to this rule can be made where there is sufficient space in the station over the gaps. Figs. 236-246, 247, 248 and 249 illustrate a few methods of installing arresters.

The objection to installing the tanks outside of the station results from the freezing of the electrolyte in cold climates. The electrolyte used in these arresters is not injured in any way by freezing, but when frozen the internal resistance of the arrester is increased about twenty times, and hence its discharge rate is decreased a corresponding amount. In other words, at double potential the discharge rate would be reduced from about 600 amperes to 25 amperes. The film characteristic up to the critical voltage remains practically unchanged when frozen. Under certain conditions the arrester tanks can be installed out of doors, and special bushings are designed for this service.

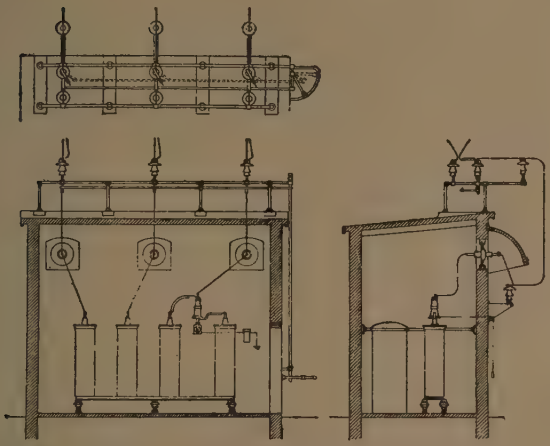


Fig. 248. Aluminum Lightning Arrester Installation for 60,000 Volt Three Phase Non-Grounded Neutral System, Showing Horn Gaps on Roof, Wall Entrances and Tanks Inside of Station.

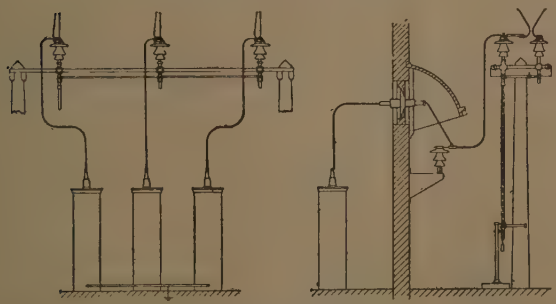


Fig. 249. Aluminum Lightning Arrester Installation for 60,000 Volt Three-Phase Grounded Neutral System, Showing Horn Gaps on Wooden Poles, Wall Entrances and Tanks Inside of Station.

OUTDOOR INSTALLATION.

Only arresters of the outdoor type, with special water-tight bushings and metal covers, should be installed out of doors. Care must be taken to see that the bushings are correctly assembled to be water-tight. In hot countries the heat of the sun should be guarded against by means of a sun roof over the arresters. The arresters may be either mounted on a platform between poles, or on a platform near the ground and surrounded by a fence. The position of the arresters should preferably be such that their operation can be observed by the station, or substation attendant. While installing arresters out of doors, great care must be taken not to let the wooden, and fibre parts of the cone stack become wet in case of rain, and to keep dust from the cones and electrolyte.

GAP SETTING.

The setting of the horn gaps of aluminum arresters is affected by several operating conditions as follows:

First; it is influenced by the wave-form. It is always the peak value, and not the effective value of potential that starts the discharge. Consequently if the generator wave has a sharp peak, the gap will spark over for a low effective value of potential, and, vice versa, if a wave shape is flat, it will require a high effective voltage to start a spark across the gap.

Second; the spark potential is less for stations located in high altitudes and the horn gaps therefore require higher settings.

Third; the spark potential is affected by the local conditions of the circuit; for example, the nearness of the horns to other metallic objects, the tendencies to resonate with some higher frequency, etc.

In consideration of the above variables, it is impossible to give a definite gap setting for different circuits of the same voltage. The best that can be done is to give a list of the gap settings which we have found give out good protection on any circuit, and give a second list of settings which should be considered as minimum values for circuits operating under favorable conditions of the three factors described above.

The following are the settings of the horn gaps for the various voltages. Installations having no attendants should have gap setting somewhat greater than stations having attendants.

Voltage	Gap Setting—Usual Limits	Short Circuit Gap
2500	.20″ to .30″	0
3300	.25″ to .35″	0
4600	.30″ to .45″	0
6600	.35″ to .50″	0
10000	.40″ to .60″	.10
12500	.45″ to .70″	.10
15000	.50″ to .75″	.10
17500	.55″ to .80″	.10
20000	.60″ to .90″	.10
25000	.75″ to 1.10″	.10
30000	.95″ to 1.40″	.10
35000	1.10″ to 1.60″	.10
40000	1.40″ to 2.10″	.10
45000	1.75″ to 2.60″	.10
50000	2.00″ to 3.00″	.10
60000	3.00″ to 4.50″	.10
70000	4.50″ to 6.75″	.10
80000	6.00″ to 9.00″	.10
90000	7.50″ to 12.00″	.10
100000	8.50″ to 13.00″	.10
110000	10.00″ to 15.00″	.10

In making a new installation of the aluminum arresters the operator should first set the gaps at the higher values given in the table, until the cells are thoroughly formed as described. Since the gaps may be closed for several minutes with only a slight wear on the aluminum plates, the operator while making the daily tests should note the gap length at which the arcs across the gaps break when resetting horns to their normal position. The normal setting of the gaps should be about double this value, or otherwise the horns will be unable to extinguish the charging current of the arrester, if once started. Furthermore, the arresters should be carefully watched for several weeks after the new setting is made to be sure that some slight, harmless, continuous surge on the line will not cause the arrester to discharge continuously.

CONNECTIONS AND WIRING.

To obtain the best protection, the path from line to arrester, and arrester to ground, must be the shortest and most direct possible.

For wiring high voltage arresters the use of copper tubing is advisable. There are several reasons for this.

In all lightning arrester installations it is necessary to provide a path to the lightning arrester, and ground with as little impedance as possible. In order to achieve this purpose, rather large wires with long bends and turns would have to be used. It is quite well known that high frequency lightning disturbances are confined to the outside surfaces of the conductors, penetrating but little toward the center, hence by using either flat strip, or tubing, we are able to secure the advantage of a large conductor, namely, a large surface, but at much less cost.

Copper tubing has the advantage over either strip or solid conductors in, that it is easily supported, requires fewer insulators, and is therefore the cheapest to install. It also presents a very neat appearance.

This copper tubing is so designed that when the wiring is complete, all joints are flush, all sharp bends are eliminated, and there are no points where corona, or brush discharge will take place.

As installations vary so much in their layout, it is impossible to provide copper tubing for wiring the arresters completely. Hence, there are listed convenient parts which may be selected as soon as the lightning arrester layout has been determined.

The parts listed consist of straight sections, bends of various angles, tees, terminals, and connectors for joining the various parts together. All of these parts, except the straight tubing, are tinned at the joints, and it is necessary only to join the sections and apply to the outside a heat sufficient to sweat the sections together.

INSTALLATION OF DISCHARGE ALARM.

When a discharge alarm is to be installed, the auxiliary cell must be connected in series with the ground connection. This should be done without increasing the length of the ground connection more than absolutely necessary. The ground wire, or pipe framework, between the arrester and alarm cell must be insulated for about 1000 volts. This can be usually done with either wood blocks, or fibre bushings.

The magnet bell, or relay, with resistance rods in series should be connected so as to shunt the cell to ground; the resistance rods next to the cell. The bell, or

relay, may be located at any place convenient, but the resistance rods should be near the arrester (see Fig. 250).

To place the alarm cell in service, fill the jar half full with the electrolyte furnished for the purpose, then pour in one-eighth pint of oil. After the plates have been replaced and before connecting in the circuit, it is best to place the cell across 250 volts, with lamps in series, as explained under "Testing and Preliminary Charging." If the bell does not ring well, some or all of the resistance may be short circuited.

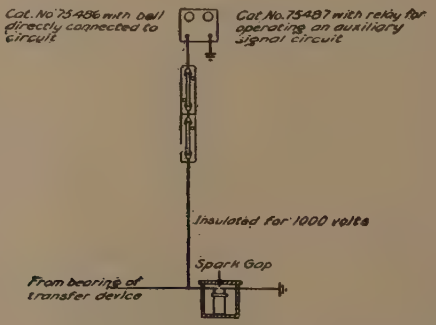

Cat. No. 75486 with bell directly connected to circuit
Cat. No. 75487 with relay for operating an auxiliary signal circuit
Insulated for 1000 volts
Spark Gap
From bearing of transfer device

Fig. 250. Connections of Discharge Alarm for Use With Aluminum Lightning Arresters.

ASSEMBLING AND FILLING CONES.

The stacks of cones are shipped, assembled and packed in iron tanks. Just before they are installed they should be carefully unpacked, and thoroughly blown out with dry air to remove any dust which may have collected

during packing and shipment. If it should be necessary to disassemble the cones, care should be taken not to touch the film surface with the hands. The cones may be held by the rim, however, as this part of the cone is never in contact with the electrolyte.

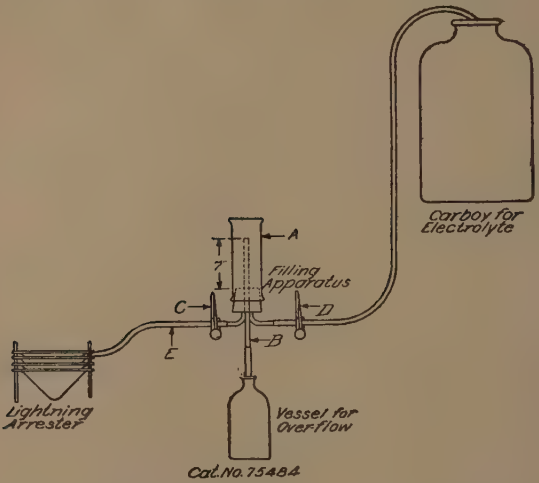
The cones should be filled with electrolyte as described below, but *this should not be done until everything is in readiness to put the arresters into service on the line.* Not more than two days should be allowed to elapse between the time of filling in the electrolyte, and putting the arrester into service, otherwise the electrolyte, standing in the cells without voltage, will dissolve the film somewhat and make it necessary to do considerable "forming up" when the arrester is finally put into service.

Great care should be exercised to keep the electrolyte and cones clean and free from dust. Impurities in small quantities cause an extra current to flow when charging, and hasten the wearing out of the cones. A considerable amount of impurity will cause such a current as to prevent the arrester from operating properly. Impure electrolyte usually shows itself gradually, and produces a large arc at the horns each day when the cells are charged.

Use only glass, earthenware, rubber or aluminum vessels in handling the electrolyte. Use such precautions as wiping the mouth of the carboy when it is opened, washing out the rubber tubes of the cone filler with water, and covering the cones if it is necessary to leave them standing outside of the tanks. Keep the tanks covered.

The cells are only partially filled with electrolyte, 4 oz. or ¼ pint should be placed in each cell. This can easily be done with the aluminum cone filler shown in Fig. 251.

The carboy should be raised about two feet higher than the stack of cones, so that the electrolyte will siphon in rapidly. A piece of glass tubing inserted in



Electrolyte should be siphoned from carboy into tube "A" until its surface has risen to the top of tube "B." Any overflow may be caught from bottom of tube "B" in a glass vessel and poured back into carboy.

Electrolyte should be released from tube "A" into cones by pinch-cock "C."

It is extremely important that the same quantity of electrolyte be put into each cone.

Hence care should be taken to:

"a" Have pinch-cock "C" closed while "D" is open and vice-versa.

"b" Have electrolyte in "A" as high as top of tube "B" and no higher before opening "C."

"c" Move tube "E" systematically, i. e., just before allowing electrolyte to run into cone or just after. This is to avoid skipping a cone or giving one a double quantity of liquid.

Fig. 251. Cone Filler.

the end of the rubber tube leading into the carboy will prevent this tube from floating on the electrolyte. The pinch cock on the tube from the filler to the cones must be near the filler, otherwise the amount of electrolyte measured will not be correct.

It is important that each cell contain the same amount of electrolyte, so as to have equal distribution of voltage over the arrester. Great care should be taken that no cell is omitted, or any filled twice. Some good system of routine should be followed to guard against this danger. Care should be taken in filling *not to wet any of the wooden, or fibre parts* used in supporting the cones. The filling tube should be always inserted half way between the supporting rods and pushed well in.

TESTING AND PRELIMINARY CHARGING.

After the entire stack of cones has been filled, and before placing it in the tank it is desirable to test out each cell to see if it has been properly filled and to give it a preliminary "charge." This should be done by connecting 250 volts A.C. to each cell successively with a bank of lamps in series. Sufficient number of lamps should be used to limit the current to 2 amperes when the aluminum cell is not in circuit. When put across the cell, the lamps may first burn bright, and if so should be allowed to dim down. *In doing this care should be taken not to allow the electrolyte to get warm.* If the lamps do not burn brightly at first it is an indication either that the cell has not been filled with electrolyte, or that the film is already formed, which can easily be determined by noting the spark when making contact.

If 250 volts is not available 500 volts may be used,

testing two cells in series. If only 125 volts is available an indication of whether the cells are filled or not may be had, but charging is not fully accomplished and special precautions must be taken when first connecting the arrester to the line as later explained. With 125 volts use only one testing lamp. If alternating current is not available, direct current may be used, but in this case reverse the polarity while testing each cell. This testing and charging usually takes about 10 seconds per cell.

FILLING THE TANKS WITH OIL.

When the stacks of cones have been filled and tested, they should be lowered into the tanks and centered, being sure of good contact between the base and tank. The tanks are then filled with oil to within three inches of the top. Care must be taken to prevent the oil from washing out the electrolyte from between the cones. The electrolyte is only slightly heavier than the oil and a stream of oil hitting the side of the stack will wash the electrolyte out. Oil may be either pumped, or siphoned in through a pipe running to the bottom of the tank, or may be poured gently into the top cone. Oil from standard iron barrels contains iron scale, *which must be removed.* It is therefore necessary to *filter the oil* by passing it through thin muslin or doubled cheese cloth.

PLACING THE ARRESTERS IN SERVICE.

The arresters when shipped from the factory have the film completely formed on each separate aluminum cone. They have, however, never been operated assembled, and

it is advisable to use certain precautions when first placing them in service.

If the preliminary charging is correctly done, using approximately 250 volts per cell, as described, and if not more than two days have elapsed since this charging, the arresters can be put in service by operating the device provided to short circuit the horn gaps, charging the cells as described under "Daily Charging." If only 125 volts were used for testing, or if the cells have been standing for a longer time than two days, or if, having once been in service, a period of two weeks has elapsed without charging arresters, it is not advisable to throw full potential on them at once. With the potential about ½ normal, start the arcs across the horn gaps, opening the gaps again immediately. This operation should be repeated about a dozen times as described under "Daily Charging." Then raise the voltage to ¾ normal value, and again start a momentary discharge across the gaps about a dozen times. Finally raise the potential to full normal value, and again start the momentary arcs several times. If the cells are in poor condition, the first arc at the gaps for each step in the potential may be white, flaring, and rise half way, or even to the top of the horns before it is extinguished, thus showing considerable current in the initial reformation. Each successive arc should show less flaring, and rise less on the horns. Finally the discharging current produces, in daylight, a bluish snappy arc, a spark, which does not rise much on the horns.

If the internal connections in the tank are poor or, if a cell has not been filled, there will be a rumbling sound in the tank if the potential is sufficient to start an arc in the oil. In such a case it is necessary to withdraw the

faulty stack of cones, and correct the trouble before proceeding with the tests. The usual cause of such trouble will be a cell not filled with electrolyte or, wet around the fibre separators between cones. If the impressed potential is not sufficient to start an arc in the oil there will be no dynamic arc at the horn gaps; there will be only a feeble spark when the gaps are diminished to the sparking length.

DAILY CHARGING, CARE, INSPECTION AND REPAIRS.

The dissolution of the films on the aluminum cones when they are left in the electrolyte is brought out in the discussion of the characteristics of the arrester.

The charging operations in the case of the arresters for grounded circuits consists merely in simultaneously closing the three horn gaps so that the full potential across the cells will cause a small charging current to flow and form the films to their normal condition.

With non-grounded neutral circuits, the charging operation is as follows: First, the horn gaps of the arresters are momentarily closed, and then opened again to normal position, thus charging the cells of the three line stacks. Second, with the horn gaps still in normal position, the connections of the ground stack of cones, and one of the line stacks are interchanged, thus making one of the charged stacks the ground leg of the arrester. This is accomplished in the low voltage arresters (1000 to 7250 volts) by reversing the position of the single-pole double-throw switches (these switches must always be in opposite directions). On the higher voltage arresters the position of the transfer switching device (Fig. 252) is reversed. Third, the first operation is repeated, so

charging the first stack of cones which was originally the ground leg. The complete charging operation takes

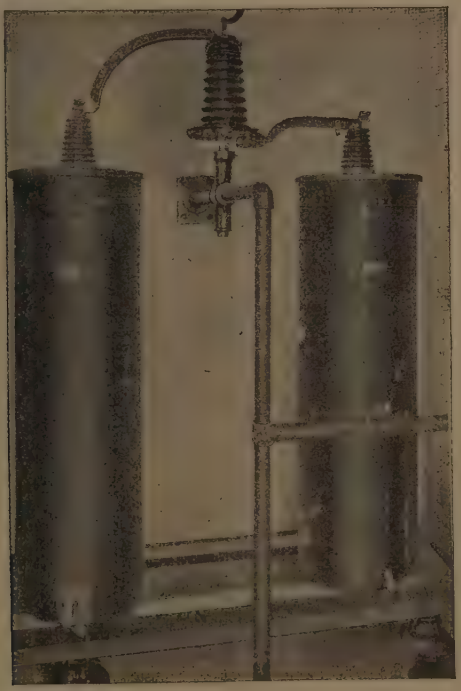


Fig. 252. Transfer Device and Two Tanks of 35,000 Volt Aluminum Lightning Arrester.

but a moment and should be performed daily. The operation is valuable, not only to keep the films in good condition, but also to give the operator some idea of the

condition of the arrester by observing the size of the arc which forms during charging. It is recommended that this daily charging of the arrester be made part of the station routine, and that records be made of the time of charging, and the size and color of the arc which rises on the horns. Too large, or too small an arc indicates that there may be an abnormal internal condition which should be investigated before trouble occurs. This will not only increase the operator's interest in the arrester, but when once he becomes familiar with the proper operations, the test gives an indication of the internal condition of the cells.

The tanks have sufficient heat storage capacity to allow the arrester to discharge continuously for half an hour in case of a recurrent discharge. *If such an abnormal condition should ever occur when the disturbance lasts over half an hour the arrester, and also the affected circuit should be disconnected.*

After an arrester has been subjected to a discharge long enough to heat it up, great care should be exercised subsequently when it is again put under the daily test. The hot electrolyte has a much greater dissolving effect on the film, than cool electrolyte. If the electrolyte becomes very warm it is better to take the same precaution in the next test, as is taken when first connecting the arrester to the circuit.

Should it ever be necessary to take the cells apart for repairs, the oil and electrolyte can be used over again, but it is desirable to change the electrolyte if it has been in service for a long time. It is recommended that before each lightning season the stack of cones be raised in the tank, and a few of the top cones inspected to determine their condition.

COMPRESSED AIR IN RAILWAY WORK.

The advantages of compressed air for railway power plants and in car houses, and repair shops are only beginning to be understood, and are not yet fully appreciated. The larger companies have become familiar with it through their experience in operating air brakes, and those that have modern shop equipment have found it convenient and reliable for hoisting purposes, and in the operation of wood and iron working machinery. In some plants, too, it is used to clean motors and dynamos, the backs of switchboards, and cushions for car seats, but the extent and variety of the service it is capable of performing has not occurred to the average run of superintendents and master mechanics. The educational process in this field seems to be very slow, and while there is generally a vague idea that compressed air may be employed to advantage for cleaning machinery, yet those troubles experienced in the operation of electrical apparatus are not always recognized as being due to an accumulation of dirt and dust, which might thus be removed. In fact, if it were generally understood that troubles and annoyances so often experienced in the operation of the power plant and rolling stock were attributable to their real cause, and that compressed air could be so readily obtained, there is no doubt that the intelligent manager would install a suitable plant for this purpose.

Much of the delay in the adoption of compressed air for cleaning machinery has probably been caused by the

cumbersome, and complicated compressing appliances that were employed for a long time; but this objection no longer exists, as simple, durable and compact air compressors suitable for this purpose are now obtainable. The electrically driven compressor is by far the simplest, and most desirable for railway shops, and it is always available, by simply closing a knife switch. The operator does not need to know anything whatever about the compressor, and as skilled attendance is not required, pneumatic appliances may be entrusted to ordinary laborers about the car shops and power houses, and the same class of help can be utilized for using many pneumatic tools. There are many little things about a shop that can be done when compressed air is available, and which effect small economies in themselves, but aggregate a considerable sum in the course of a year. The flexibility of the system is, of course, greatly in its favor, and the employment of portable motor-driven compressors in large shops has made it possible to utilize pneumatic appliances in all parts of the works where current is obtainable. The subject is a fruitful one for superintendents who desire economy of operation, and at the same time endeavor to maintain a high degree of efficiency in equipment.

EFFICIENCY OF TROLLEY WIRE.†

No department of electric railroading has received less attention than the transmission line, and particularly the trolley wire. In the construction and maintenance of an electric railroad no expense is spared to obtain power-station equipment of the highest efficiency while the trolley wire, which is just as essential for operation, is generally purchased with no restrictions on the quality of material.

The entire development of electric traction has taken place within the past twenty-five years, and this short period of time has witnessed an almost fabulous advance in the improvement of power stations and rolling stock. Higher voltages, greatly increased electrical output, heavier and more efficient cars capable of increased speeds have been noticeable on all lines. The increasing demands of traffic and the necessity of economical operation have forced the development of machinery of high efficiency. In spite of the great advance along all other lines, the trolley wire of today is not essentially different from that at first installed.

At the present time there are over 25,000 miles of electric lines in the United States. Calculating the value of the trolley wire in use at the current price and assuming the average weight per mile as 2,000 pounds, this shows a total investment of $8,000,000. This wire is the artery of the entire system, and any injury to it cripples the operation of the road, and decreases thereby the efficiency of the expensive generating equipment, and yet an ex-

†Abstract of a paper read before the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society, December 31, 1908. The author, Carl F. Woods, is connected with the Arthur D. Little Laboratory, Boston, Mass.

amination of the records of roads operating many hundred miles of track shows that a broken trolley wire is almost a daily occurrence.

Numerous attempts have been made to specify the necessary characteristics of trolley wire, some of which have failed because of an incomplete understanding of the demands upon the material, and many more on account of ignorance of the processes of manufacture, and the defects inherent to these processes. The determination of the qualities necessary in an efficient material must always be preceded by a thorough understanding of the conditions which it must meet, and by a careful study of the material itself, and the limitations imposed by manufacturing processes.

The trolley wire in general use in the United States is made from hard drawn copper, the sizes and shape varying considerably, but circular wire having a diameter of 0.364 inches, which correspond to No. 00 on the Brown & Sharpe gauge, is perhaps the most common form of construction. Ordinary soft copper does not have sufficient strength for this service, so that reliance has had to be placed upon either steel, bronze, or hard-drawn copper. While steel wire has the requisite strength, it is subject to severe corrosion from the weather, and has vastly greater electrical resistance. The silicon, phosphorus, and other bronzes of a similar nature possess great strength, but all have the serious defect of much lessened conductivity. Soft copper wire has a strength of about 34,000 pounds per square inch, while hard-drawn wire can be made having a strength of as high as 67,000 pounds per square inch. Hard-drawn wire, although possessing some serious defects, has therefore been accepted as being much better than the other materials available for the purpose.

In standard construction, trolley wire is suspended in spans of 100 feet on straight lines, and in shorter spans on curves, the distance depending upon the radius of the curve, local conditions, etc. These spans are supported by ears which vary in construction, but for the most part depend upon a fixed mechanical grip of the wire. In the earlier construction, ears were soldered to the wire, a process which annealed the hard-drawn copper with the consequent reduction in tensile strength, but this practice is now rapidly becoming obsolete. The wire, therefore, is subjected to the pull of its own weight, to the extraordinary stresses of ice and snow, and to severe pounding from the trolley wheel. In addition the wheel passing along the wire gives to it a wave motion, which proceeds along the wire until an ear, or other fixed support is reached, where the wave is suddenly checked, with a consequent sharp upward bend, followed by a series of bending stresses diminishing in force as the wave motion dies out. On a busy line, where cars are operated on a small headway the wire is subjected to practically a continuous effect of this nature, and in addition to this must be capable of carrying a large amount of power in order to diminish the outlay in feed wire.

To give efficient service under the conditions above noted, trolley wire must possess the following qualities: Conductivity, tensile strength, flexibility, homogeneity, and toughness.

Each of these qualities is essential, and no one of them can be increased beyond a certain point without a proportionate reduction of one or more of the others. For example, certain wires have been made from alloys of copper and tin which have high tensile strength, great

toughness and homogeneity, but are lacking in flexibility and have a conductivity only half that of pure copper. On the other hand, by proper drawing, wire can be made very homogeneous, flexible and tough, but lacking in tensile strength, the conductivity being unimpaired. To recapitulate, high conductivity is necessary for economical operation; tensile strength to withstand the abnormal stresses; flexibility to enable stringing and to allow the wire to adjust itself under strains and blows; homogeneity that the stresses may be uniformly distributed along the wire, and toughness to withstand kinking, wrenching, and slow distortion without giving way.

Attention naturally turns next to the methods of determining to what extent wire possesses these essential properties. The determination of conductivity is very readily and accurately made with a Wheatstone bridge, or one of the several appliances based upon the same principle which are especially adapted for trolley wire. Tensile strength may be determined in a testing machine of suitable capacity, but owing to the nature of copper the elastic limit cannot be determined by a drop of the beam, as the metal apparently yields quite steadily, up to the breaking point. Numerous conflicting figures are in print regarding the yield point of copper, but as a stress and strain diagram shows a nearly perfect curve, the actual elastic limit can only be accurately determined by applying increasing loads for a definite length of time, and measuring the permanent set in each case. Such a procedure is obviously too complicated for commercial testing, so that the elasticity of the wire has to be judged by other means. Under ordinary circumstances, power to resist the effects of twisting is not necessary for conducting wire, but the torsional strength

measures indirectly, but accurately, two of the most important mechanical properties that a wire can possess, namely, homogeneity, and toughness. In a tensile-strength test, the maximum tensile load is largely a factor of the cross-sectional area, and the amount of work which has been put into the hardening of the surface. This test will detect inferior drawing, or inherent weakness of the copper, but it gives no idea of the power of the wire to resist distortion, nor of defects, such as oxide seams which run lengthwise of the wire, and do not have a cross-sectional area of sufficient size to affect the breaking strength. Under a torsional strain, however, such defects are quickly noted. If the wire contains an oxide seam as above spoken of, the twisting will open it up, and at once lessen the strength of the wire. If the wire is of unequal hardness, the twists will tend to bunch up in the softest portion and very noticeably show this spot. Inferior copper not only shows a very low number of turns, but splinters and slivers of metal appear on the surface which in very bad wires fall off to such an extent that a paper held beneath the sample during torsion will show a considerable collection of copper fragments. Non-homogeneous copper, due either to impure metal, or uneven drawing, will show a great difference in the number of turns which different specimens will stand without breaking, while high-grade metal which has been carefully drawn twists evenly and uniformly, with no slivering, and shows little difference in the number of turns on different specimens. It is, therefore, desirable to make at least three torsion tests, whereas one tensile test is sufficient to obtain an accurate measure of the strength.

In the appended table No. 1 are given a series of tests which clearly illustrate the four general divisions into

which the trolley wire of commerce may be divided by reason of difference in physical qualities. Specimens A, B, C, having tensile strengths of 5,500 pounds or higher, and torsion tests averaging about thirteen, represent wire lacking toughness which has been given a high tensile strength by drawing. Specimens D, E, F, having tensile strengths around 5,300 pounds, and torsion tests of about fifteen, are wires lacking both toughness and surface hardness. Specimens G, H, I, having tensile strengths of about 5,100, but torsion tests of approximately twenty-three, are typical of wires in which the torsion has been obtained at the expense of tensile strength, while specimens X, Y, Z, with tensile strengths over 5,400 pounds, together with torsion tests of twenty-six, and even higher, represent the best trolley wire which can be made at a reasonable price.

TABLE NO. 1.

Sample No.	Diameter Inches.	Torsion Turns in 10″.	Tensile Load Lbs.	Conductivity %.
A	0.365	14	5,650	98.4
		12		
		9		
		—		
		Av.....12		
B	0.364	11	5,550	98.6
		12		
		11		
		—		
		Av.....11		
C	0.362	18	5,500	98.2
		14		
		16		
		—		
		Av.....16		
D	0.365	18	5,260	98.6
		16		
		18		
		—		
		Av.....17		

Sample No.	Diameter Inches.	Torsion Turns in 10″.	Tensile Load Lbs.	Conductivity %
E	0.365	14	5,270	98.7
		15		
		16		
		—		
		Av.....15		
F	0.364	14	5,370	98.7
		13		
		14		
		—		
		Av.....14		
G	0.364	21	5,070	98.9
		23		
		22		
		—		
		Av.....22		
H	0.364	22	5,110	98.4
		25		
		21		
		—		
		Av.....23		
I	0.365	24	5,210	98.4
		25		
		24		
		—		
		Av.....24		
X	0.364	27	5,400	98.3
		30		
		28		
		—		
		Av.....28		
Y	0.364	25	5,490	98.4
		27		
		26		
		—		
		Av.....26		
Z	0.364	25	5,590	98.2
		28		
		25		
		—		
		Av.....26		

Of these four classes there is again a distinction in, that the first two represent copper of an inferior grade, which cannot be made the equal of the wires of the last two classes by any treatment in the rod mill. On the other hand, wires of the last two classes are both made from excellent copper, although specimens X, Y, Z are wires greatly superior in all respects to the preceding three. It is interesting to note that all of these wires have practically the same conductivity, which shows clearly the fallacy of attempting to value trolley wire by conductivity and tensile strength alone, as is so frequently done.

It is therefore necessary not only to obtain high-grade copper, but also to secure the proper balance between tensile strength and torsion, as these two properties are correlated, and an increase in one, beyond a certain point, results in a proportionate decrease of the other.

The preceding remarks have shown the conditions under which wire must work, and the qualities which are necessary to successfully meet these conditions. Attention must now be turned to the process of manufacture to determine how these qualities may be obtained, and what defects of such processes injure the finished wire. For this purpose a brief review of the industry is necessary.

In the refining furnace the copper, which is already at least ninety-six per cent pure from the blister furnace, is oxidized by air until a large part of the impurities have been removed, and copper oxide is formed in considerable excess. Cuprous oxide is readily soluble in molten copper, and acts as a powerful oxidizing agent by giving up its oxygen to any metallic bases present, so that an excess of oxide insures the presence of all metal-

lic impurities in the oxide form. The excess cuprous oxide is then removed by burying a piece of green wood in the molten mass and covering the surface with charcoal. This process must be stopped within very narrow limits, as over-reduction will throw the impurities back into the metallic state.

The influence of cuprous oxide has been studied by Mr. Patch of the Detroit Copper Company, Dr. Edward D. Peters, Jr., who is without doubt one of the best authorities on the metal in this country, and by the well-known German authority, W. Hampe, among many others. Many of the impurities in copper have been found to be much more injurious when present in the metallic state, than when in the form of oxides, and one effect of the cuprous oxide, as above mentioned, is to convert these impurities into the comparatively inert and harmless form, and so improve the quality of the metal. In large quantities, however, it is known to harden copper, while at the same time causing it to become short or brittle, and according to Hampe the presence of one per cent produces a diminution in toughness.

It is therefore possible to treat low-grade metal so that it will have high conductivity, although the large amount of cuprous oxide present greatly reduces the toughness. In purchasing copper for drawing trolley wire the manufacturer insists upon conductivity, but as a rule cares little for the other physical qualities, as he can obtain sufficient tensile strength by drawing. Lake copper possesses both high conductivity and excellent mechanical qualities, but this kind of copper costs from one-eighth to three-quarter cent per pound more than electrolytic. Why the latter should be inferior to Lake

is difficult to explain, but experience shows that the general run of commercial electrolytic copper is by no means uniform in physical qualities, and as a general thing is distinctly inferior to Lake for wire-drawing purposes. The cheaper price of electrolytic, results in its use by many manufacturers, although they frequently understand that the wire will be inferior.

The refined copper comes to the rod mill in bars weighing about 200 pounds each, approximately ten of which are used in the manufacture of a mile of wire. These bars frequently have ridges along the sides, due to faults in casting, and the surface is often covered with a layer of oxide. These bars are heated in a furnace until sufficiently soft for rolling and are passed through a series of rolls diminishing in size, until a rod of the proper diameter is obtained. The rod is then cooled and drawn through dies, the rods being connected by brazing. The dies give the wire a dense, hard exterior coating which increases its tenacity. As the strength obtainable is almost a direct factor of the work expended upon the wire, the smaller the size, the greater the tensile strength per square inch, so that the strength of the trolley wire is readily varied by changing the size of the rod, and the number of dies.

One of the most serious defects occurring to wire at this point is from ridged bars, as described above. Ordinarily the bar will not be sufficiently heated to dissolve the copper oxide on the surface, so that as the softened bar enters the first passes of the rolls, the ridges are lapped over, enclosing the oxide scale. The subsequent passes, and the drawing through the dies obscure this flow almost entirely, but it remains a serious menace to the toughness and the resistance to wear of the copper,

as has been previously shown in remarks on the torsion test.

A second cause of trouble arises at the same point by overheating the copper in the furnace, in which case copper oxide is formed on the surface, and quickly dissolves through the entire bar, thereby increasing the oxide content, and tending toward the production of brittleness. Both of these dangers can be avoided by careful selection of the bars, and by proper regulation of the temperature of the softening furnace.

As the production of the hard surface from drawing is at best a rather delicate operation, careless handling, uneven welding of the rods, and unequal temperature of the wire while passing through the dies will all produce noticeable defects in the quality of the finished wire, so that care throughout the mill is absolutely necessary for the best results.

It appears, therefore, that the most efficient wire must possess not only high conductivity, but the maximum torsion, and tensile strength possible in commercial copper, and that to obtain this it is necessary, first, to use high-grade copper and to prevent an excess of cuprous oxide entering it at any stage of the manufacture, and, secondly, to select as perfect bars as possible, and to observe extreme care in every treatment through which they pass. The question at once arises, can such wire be purchased at a commercial price? The writer must admit that this high-grade wire cannot be obtained at the ordinary market price, but requires the payment of a premium of one-half cent per pound. To produce wire of this grade consistently, the wire manufacturer must use the higher-priced Lake copper, and observe unusual care in its treatment, so that he is justified in demanding

a higher price. Experience in the use of this wire has shown conclusively that it is well worth the additional cost.

The appended table No. 2 gives the results obtained upon thirteen consecutive miles of trolley wire made from selected bars of Lake copper. The tests were made upon each mile of the wire, and the results show the great uniformity obtainable with proper care. It should be said in this connection that this wire was not made as an experiment, but was drawn by a certain wire company as a part of a regular business contract.

TABLE NO. 2.

Sample No.	Diameter Inches.		Torsion Turns in 10″.	Tensile Load Lbs.	Conductivity %.
1	0.363		22½	5,470	99
			24¾		
			22½		
		Av.	23½		
2	0.364		23	5,490	98.7
			25		
			23		
		Av.	23½		
3	0.363		19¾	5,400	97.8
			25½		
			17½		
		Av.	21½		
4	0.363		23½	5,470	98.8
			25½		
			23½		
		Av.	24		
5	0.363		22½	5,450	97.8
			21¾		
			24		
		Av.	22¾		
6	0.363		24	5,500	98.6
			20		
			24¼		
		Av.	22¾		

Sample No.	Diameter Inches.		Torsion Turns in 10″.	Tensile Load Lbs.	Conductivity %.
7	0.363		22½	5,420	97.8
			24		
			23¾		
		Av.	23½		
8	0.365		23	5,510	98.5
			24		
			20		
		Av.	22		
9	0.363		24	5,540	98
			19½		
			23½		
		Av.	22		
10	0.363		21	5,470	98.8
			23		
			21		
		Av.	21½		
11	0.363		22	5,490	98.8
			22½		
			23		
		Av.	22½		
12	0.363		26½	5,500	98.5
			26½		
			23½		
		Av.	25½		
13	0.363		23	5,450	98.7
			20½		
			24		
		Av.	22½		

The point must be kept clearly in mind, however, that even the best of wire is of little value if improperly used, and the consumer must realize that the same degree of care which he insists upon from the manufacturer is essential in the handling and stringing of the finished wire.

The study of copper wire and the demands made upon it show the great need of a more thorough knowledge of this material. Owing to the minute quantity of impurities which exert a marked effect upon the qualities of copper, a chemical analysis is too difficult for technical purposes. The iron and steel industry is largely controlled today by microchemistry, and, in the same way, there is a future for this same practice in the copper industry. Of first importance is the careful working out of the copper-cuprous oxide system, with the determination of the number of phases occurring, and the physical properties incident to different alloys. Doubtless much of this information is already in the hands of the copper refiners, but it remains for chemical engineers, and chemists interested in industrial materials to verify and complete the work for the consumer. This should afford a good field for experiment stations, and research students generally.

A NEW TYPE OF ELECTRIC LOCOMOTIVE.

Fig. 253 shows a novel type of electric locomotive which has been designed jointly by the General Electric, and American Locomotive companies for trying out a scheme of transmitting power from the motors to the drivers through side-rods, instead of by the ordinary methods.

The locomotive is designed for a tractive effort of 30,000 pounds at a speed of eighteen miles per hour, with a maximum speed of fifty miles per hour, and will operate equally well in either direction. It has been tried out with temporary motors of a somewhat smaller capacity, and the tests have demonstrated conclusively that the design is entirely satisfactory in every way. It is proposed to extend the cab over the entire length of the machine, when the proper motors are installed on the locomotive. The present cab and guards are only for the temporary protection of the apparatus now installed.

One of the principal advantages found in this type of construction is that a motor of large diameter, and small air gap can be used in conjunction with small diameter driving wheels, and at the same time the motor can be spring-supported. The same motor equipment can also be used on locomotives with different diameters of driving wheels, thus permitting the interchange of equipment on freight, and passenger locomotives. This type of locomotive is as well adapted for operation with direct-current motors, as with those of the alternating current type.

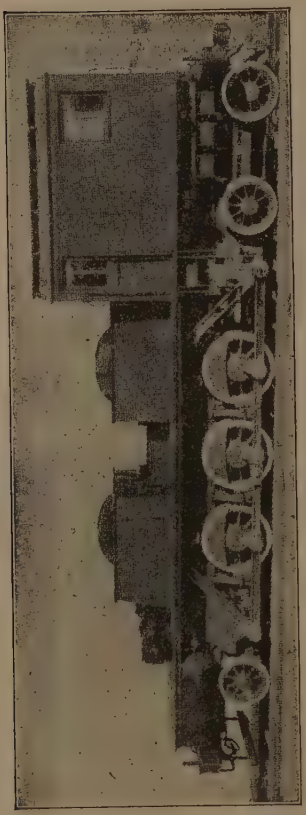


Fig. 253. Experimental Side-Rod Electric Locomotive.

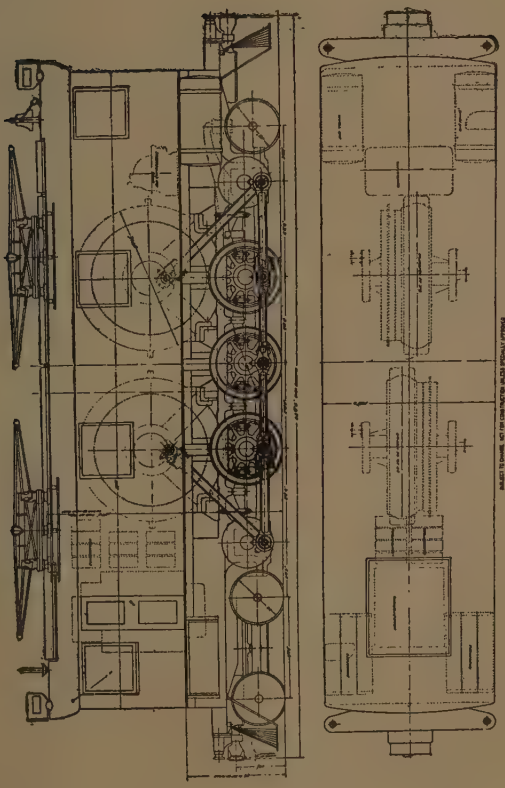


Fig. 254. Plan and Elevation of Electric Locomotive.

The electrical control is arranged in such a manner that the motors start as repulsion motors with short-circuited armatures, and are changed over to series-repulsion motors for the higher speeds. This arrangement eliminates running with a short-circuited armature on high voltage, and at the same time gives a high torque at starting.

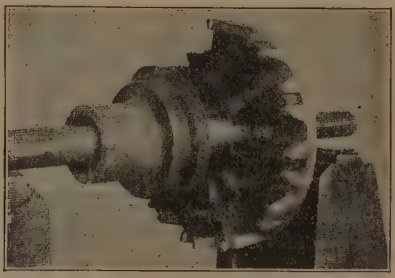


Fig. 255. Flexible Coupling, Partly Assembled.

The armatures are similar to those of an ordinary direct-current machine with equalizer rings. They have multiple drum windings, with the bars soldered directly into the commutator segments.

The field or stationary windings are of the distributed type, and are made in two sections, the exciting and the inducing windings. The former has the same function as the field winding in an ordinary series motor, while the inducing winding introduces the working torque when the motor is connected as a repulsion motor.

All parts of the running gear, such as wheels, driving boxes, axles, springs, spring rigging, trucks, etc., follow standard steam locomotive practice.

Counterweights are used on the driving wheels to balance the side-rods, and it should be noticed that there are no reciprocating parts and therefore a perfect balance can be obtained.

An interesting mechanical feature is the flexible coupling inserted between the armature shaft of the motor, and the motor crank. This consists of a series of leaf springs arranged radially around the motor shaft and of such a strength as to carry the entire torque of the motor with an amount of deflection which will reduce the effect of the pulsating torque of a single-phase alternating current motor to a minimum. The accompanying plan and elevation (Fig. 254) shows the general arrangement.

THE PASSING LOCOMOTIVE ENGINE.

The life-like passenger locomotive, quivering with repressed energy at the station, and the massive mogul straining up long grades toward the backbone of a mountain range with the labored breathing of some colossal monster, thrill the imaginative spectator no less today than did the primitive engine when steam transportation was experimental, and before the history of the locomotive's marvelous feats of speed and strength had been written.

The substitution of the electric locomotive for the noisy, smoke-breathing monster of the rails will mark the elimination of a feature of transportation no less picturesque in its way than the giant clipper ship with her mystifying multitude of lines and her mountain of canvas and the substitution of the fast passenger steamer for the windjammer on the ocean, and the replacing of the sweep-propelled barge on inland waters for the mule-drawn canal boat.

THE ELECTRIC FREIGHT LOCOMOTIVE.

The economics which have resulted from the operation of long and heavy freight trains by one locomotive are not possible where heavy grades are encountered, but from the desire to apply the principle to as large an extent as is practicable, additional locomotives are then used for the single train. When steam is worked nearly full stroke in the cylinder, as is usual in ascending

grades, the limitations of the boiler are soon reached, and it is necessary to reduce speed, and steam freight locomotives ascending 2 per cent grades seldom exceed six to eight miles per hour. Even when three very large consolidation engines are used on heavy grades under present conditions, the most economical trainload is hauled at these very low speeds, and a large number of locomotives is required for the service. Grade operation is expensive, therefore, not only on account of the large amount of fuel burned, but also because a large equipment is necessary, and the cost of maintenance of so many heavy locomotives is a serious item. The electric locomotive, either direct current or alternating current, can exert a constant horsepower and tractive force over a much larger range than the steam locomotive, and its operation is only limited in speed by the heating of the armature and field coils.

As now constructed, it is safe to say that a given tractive force in an electric locomotive can be applied at a speed three times that of an equal force in the steam locomotive, and electric locomotives having the same weight on drivers can ascend grades with heavy trains at speeds of 20 to 24 miles per hour. The electric locomotive weighs much less per horsepower, as the whole weight is on the drivers, and the constant haul of dead weight on the trucks of both engine and tender of steam locomotives is saved. The fuel cost of this item alone in operating heavy grades must result in a large credit to the economy of the electric motor. It is reasonable to expect that the cost of repairs of electric locomotives will be much less per mile, or ton mile, and the expense for maintenance will be further reduced by the fact that fewer units are required for a given traffic. If the in-

terest, depreciation, maintenance, and cost of operation of three large steam freight locomotives is compared with that for one electric locomotive which will perform equivalent work on heavy grades, it will make such a favorable showing as to at least compel further investigation, and no doubt this will soon be followed by a complete demonstration in practice.

It is for the above reasons that the operation of freight trains by electricity on the steam lines will be first applied on the heavy grades, and several railroads have already ordered estimates for electric operation for such points on the line as are difficult of operation. An instance of this is the proposed electrification of Proctor Hill, on the Duluth Missabe & Northern, and the grades on the Cascade Mountains, both on the Great Northern and the Northern Pacific. The probabilities are that the Pennsylvania Railroad will change its alignment over the Allegheny Mountains, thus avoiding the horseshoe curve and using electric locomotives. Such an alignment might have heavier grades than the present one, and yet, be operated by electricity more economically.

WHY STEAM ROADS ADOPTED ELECTRICITY.

If it is believed by some that sentiment, or a desire to be very modern, has made the steam roads anxious to adopt electricity as part of their motive power, they are very much mistaken. The reason why the advisory and executive forces of steam roads have moved to utilize electricity as an adjunct to their present systems is simply, because the loss of traffic they would otherwise sustain made it an imperative business measure. The local traffic of all large steam roads within a short dis-

tance of New York City will be handled in the next two years by electric means. To become duly impressed with this view of the case it is only necessary to visit the neighborhood of the New York Central above 42d street, or 33d street and 9th avenue, where the gigantic station of the Pennsylvania Railroad will be constructed. Millions of dollars have been spent already in making excavations 75 feet deep over an area equal to 15 or 20 city blocks. The cost of this real estate with the houses standing was enormous, but they have all been torn down to make way for the new electrically equipped station, electrically lit tunnels, and electrically operated cars. A sum, variously estimated to reach from $40,000,000 to $60,000,000, is to be spent by the above roads respectively, in order to retain, and further develop their business as carriers of the public, and transporters of freight.

An enumeration of a few instances outside of New York where electricity has been formally recognized as the most economical form of energy for use over long distances will prove interesting. The longest run of this kind is from Indianapolis, Ind., to Lima, O., by way of Dayton, an interstate line nearly 200 miles in length. The average speed is about 30 miles an hour and the fare 1½ cents a mile. The next long run by electricity is made by the Lake Shore Electric, from Cleveland to Toledo, a distance of 120 miles. The run is made at an average of 25 miles an hour. As regards other lines of the interurban class, follow 22 belonging to the middle West, and about five in New York State, whose lengths vary from 30 to 80 miles. The lines at present in operation in New York State are as follows: The Hudson Valley, 60 miles long; the Rochester & Eastern Rapid,

44 miles long; the International (Buffalo to Olcott), 37 miles; the Albany & Hudson, 37 miles long, and the Fonda, Johnstown & Gloversville, 33 miles long. It makes very little difference whether these roads are disparagingly entitled only trolley roads or not; they are and have been winning their way steadily to the front. This fact may be accepted as an axiom in the new world of railroad work, which has developed in the past ten years, that wherever an electric road parallels a steam road the steam road loses money. It is just as good as a passenger and freight carrier; it can run just as quickly, and it can stop at a variety of points convenient to those patronizing the road without losing much on its time schedule. This fact, hammered home by the experience and receipts of electric roads, has been duly digested by the better class of thinkers of the steam traction systems. They have felt compelled to save themselves from the loss of a vast amount of transient, and local business in the near neighborhood of large cities by adopting the weapons of their competitors. The New York Central reaches out 35 miles beyond New York City, the Pennsylvania will reach out over 50 miles from New York City—with its new electric passenger and freight service.

The last lesson in railroading was not taught by the older pupil, but by the newer. Steam roads, it seems, to save themselves are rapidly becoming electric roads.

CENTRALIZED CONTROL OF POWER PLANT AUXILIARIES.

In recent power plant contruction, a valuable improvement is the concentration of controlling apparatus for auxiliaries on special panels of the main switch-

board. Thus far the principle of centralized control—which is remote control when viewed from the other end of the line—has been applied mainly to oil-switch circuits; but, with the increasing use of small motors for pump driving, valve operation, fan running, machine service, coal and ash handling, air compressor work and the like, it is becoming more and more important that the man in charge of the main switchboard shall be able at any moment to start or stop a given piece of machinery. It has taken power plant designers a long time to break away from the idea that the only place for a motor switch, is within three or four feet of the motor itself. The cost of controlling from a distance is slight in comparison with the increased flexibility of operation and, in cases where electromagnetic switches are not needed, it is simply a matter of a little extra wiring.

In these later plants, switchboard panels have been provided for the control of a considerable variety of auxiliaries. The lighting circuits of oil storage compartments, coal pocket subdivisions, pump rooms, pipe tunnels, power house machine shops, boiler and engine rooms, the motor circuits for the crane, if that is electrically driven; circuits for pumps, fans and other auxiliaries as suggested above are all suitably controlled by primary switches on the auxiliary panels. Such an arrangement in no way prevents the location of parallel switches close by the equipment, and it is a wise move, considering the broadening requirements of power house operation, to duplicate controls in certain instances.

It ought to be possible in any plant where the high-pressure steam piping is controlled at certain points by motor-driven valves, to operate these valves from the switchboard as well as from the boiler room floor. The

location of engine stop buttons on the switchboard, as well as at other points, is an example of the increase in flexibility which is approved by modern designers.

Installation of motor switches for starting and stopping coal conveyors, and crushers is certain to save labor in the long run, for these motors are almost always located in rather inaccessible spots, in comparison with the balance of the machinery. Even if they cannot be started from the main switchboard, on account of the inconvenience of rheostatic control on panels already crowded, a good deal of extra wear and tear may be saved by installing main knifeswitches of the quick-break type in these circuits, and distributing from the main switchboard. In the same way the switching of special lighting circuits at the main board tends to save needless waste of current in out-of-the-way places, particularly if pilot lamps are used in connection with the switches.

These improvements add very little to the already extraordinary cost of large modern switchboards, but they increase the operating flexibility of the plant, and open the way toward the stoppage of many small leaks. In some cases, special panels are now devoted entirely to the support of instruments reading voltage at remote points, current and power in different feeders taken in groups. Steam gages, indicators and other instruments are being paneled also, close by the main board, for there is really no logical reason why the measurements of power plant energy in the varied stages of its production should not be co-ordinated.

Intelligent operation demands a knowledge of all the existing conditions, and if present indications hold, the day is not far distant when the operating executive of

every new plant of importance will have all the physical data, steam, electrical, thermometric, flue gas indications, etc., concentrated in the few feet of space formerly devoted exclusively to electrical measurements. In many cases, the complication of distantly operated electromagnetic switches will not be needed, but the main control must, eventually, lodge at or near the switchboard. Scattered switches and instruments may supplement the grouped units, but the latter will be none the less essential. The working out of all the details will naturally vary with local conditions.

INCREASING THE PROFITS OF INTERURBAN RAILWAYS.

Profits may be increased upon an interurban railway in but two ways—by increasing the traffic or by reducing the cost of operation. Both of these methods are constantly being attempted by progressive roads, but there is little doubt that increase of traffic offers greater opportunities for success than do lessened expenses, under present conditions. Very few electric interurban lines are operated at more than 20, or 25 per cent of their full capacity, figuring on the maximum number of single cars which can be safely forced over the route in a given time. A double tracked line with cars operating at a maximum speed of 50 miles per hour, ought to be able to pass individual train units on each track at five-minute intervals in perfect safety with suitable operating rules, but the traffic seldom warrants anything less than a 15-minute interval on through interurban routes. The extended use of the multiple-unit system of control in interurban equipments is a potential advan-

tage that has as yet not been widely utilized in doubling or trebling train capacity. The great majority of interurban trains are composed of single cars, and the full resources of a road equipped with train control will not be drawn upon until the single car gives way to the multiple-unit train running upon the shortest headway possible with the single car itself.

The cost of operation of an interurban line is so much lower per mile of track than the cost of running a great city system, that an increase of traffic on the former is relatively more profitable, and there is every incentive to develop new business on a line which possesses the percentage of reserve carrying capacity which characterizes most interurban systems. The gross earnings per mile of track on a city road may be four or five times those of the interurban, but in such event the operating cost is likely to be six or eight times as great on the urban lines. Maintenance of way, taxes, and wages per mile of track or per car mile are vastly greater on the city system, notwithstanding the larger car mileage and extent of the urban road. Any increase in profitable car mileage on an interurban road is therefore bound to be a powerful factor in augmenting the profits. Interurban fixed charges remain about the same for an enormous increase of traffic, and the extra cost of carrying an additional carload of passengers is small in proportion.

These are some of the reasons why it is getting to be more profitable to make special efforts to increase interurban earnings than to reduce interurban expenses of operation. Of course, one would not for a moment counsel neglect of expenses, but it is a question if these are not down pretty close to bed rock on many systems. A possible source of waste on an interurban line is dead

mileage. In case extra cars are to be run over part of the system, from a car house to some objective point where a large return traffic is anticipated, it is usually a better plan to allow these extras to carry passengers on the outward as well as the inward trip, than to shut them up, and refuse fares in the direction of their destination. The steam railroads are giving a great deal of thought to dead mileage, and while the conditions on electric railways are in no sense as burdensome in this respect, it is well to remember that every idle movement of a car consumes power, and costs heavily in wages in proportion to the distance covered.

At the power house end of the line, equipment is undergoing radical improvements, and the steam turbine, and gas engine have both opened up a field of promise in respect to power economy on small roads. Perhaps the most notable advantage of the turbine for a small road with a poor load factor is its light load economy, while the gas engine plant offers low fuel consumption, even in small sized installations. There is also room for improvement in transmission and distribution losses, including the perennial rail bond question. On small roads, the distribution of car labor is frequently faulty, and in efforts to approach an operating ratio of 50 per cent, the arrangement of conductors' and motormen's time is well worth studying. Repair shop methods on small roads—and any interurban line is essentially a small road in comparison with a large city system—are often full of expensive makeshifts. It is also sometimes forgotten that high-schedule speed means fewer cars in service for a given interval.

Established interurban railways cannot create traffic where none exists, and there is a reasonable limit to

advertising. But this is a growing country, filled with almost unparalleled national resources, and opportunities. The interurban line of today is no longer a disjointed link between two adjacent city systems—it is an actual railroad, without regard to the motive power used, and is certain to become more and more influential in the community served, as time goes on. There is much to learn from steam railroad experience, and the tendency of the steam and the electric line to supplement each other is so marked, that the new business-getting methods of the older systems are in many cases applicable to the newer.

THE PRESERVATION OF WOODEN TIES AND POLES.

The firm of Himmelsbach Frères, of Fribourg, Baden, has been conducting a large number of tests on methods of preserving wood, particularly for use as railway ties. This company has furnished 20,000 wooden ties impregnated with coal tar for the railway through the Simplon tunnel, and has obtained fairly good results with this process of preservation. The method employed consists in passing the ties into hermetically sealed ovens, where they are heated, and the air exhausted until the pressure falls to twenty-four inches of mercury or less. Ten minutes afterwards the coal tar, previously heated, is introduced, the exhaustion within the oven being maintained during this time. The oven is then maintained at a temperature of about 105 degrees centigrade by means of a steam coil placed in or beneath it. Heating continues for four hours, after which the air pressure is increased until it reaches two atmospheres.

Practically the same process is followed in treating pins, and other wooden articles. This method, while not difficult, is not as simple as another now being tried, and known as kyanization. It depends upon the antiseptic properties of bichloride of mercury. It has been shown that a solution containing one part of bichloride of mercury to 10,000,000 of water, arrests the development of micro-organisms, and one part in 3,000,000 suppresses them. The process consists in preparing a two or three per cent solution of the bichloride of mercury in water in large vats of concrete. The wood to be treated is plunged into these vats, and allowed to rest there for some time. Chemical tests of wood thus treated show but a slight penetration of the solution. It seems to be limited to the exterior surface, but as the preserving action of this treatment lasts for a considerable time, it is possible that the penetration is really considerably deeper, and although too dilute to be indicated by chemical tests, yet it is sufficient to prevent decay. This process was used some years ago, and a table is given showing the results obtained on various railways. On some of these roads poles treated in this way were erected in 1877, of which from thirty to thirty-eight per cent were in use in 1903. Poles erected in 1883 to 1886, had from eighty-two to ninety-seven per cent still in service. Of poles erected in 1891 and 1892, all are still in good condition. The postal and telegraphic department of Bavaria has had poles treated with bichloride of mercury in service for thirty years, and has found from statistics that the average life of such poles is seventeen and one-half years.

TREATMENT FOR ELECTRICAL SHOCK.

Writing in the Engineer and Mining Journal, Richard Lee says:

There is a difference of opinion as to whether alternating-current, or continuous-current shocks, under certain conditions, are the more dangerous. It is well to remember, however, that a high-potential alternating circuit should not be regarded as safe to handle, even when the current has been shifted off, until it has been connected to earth and so practically discharged.

A live wire may often be handled without inconvenience when standing on an India-rubber mat, or on a dry-wood floor, but it is a safe rule to avoid contact with any part of an electrical apparatus, without thoroughly understanding what one is doing. The symptoms of an electrical shock are as follows: (1) Stoppage or weakening of the action of the nerves; (2) contraction and stiffening of the muscles; (3) stoppage or weakening of the action of the heart. The contraction of the muscles is what prevents the victim from letting go after grasping a live wire.

A person who has received a severe shock may become unconscious, and seemingly cease to breathe. None of these symptoms necessarily indicates death, and under no circumstances should remedial measures be abandoned until a physician has pronounced life extinct. It is most likely that many victims have been given up for dead after an electric shock, when the continuous application of further remedies might have restored them. A number of cases are on record where subjects who have received severe shocks have been unconscious for more than 30 minutes without the slightest discern-

ible heart action, and still have recovered because of the artificial respiration applied.

In treating a victim, it is advisable to elevate the body and legs so as to send the blood to the brain, which action may prove a remedy for syncope, a condition often resulting from such a shock. If the heart has stopped beating, it is sometimes possible to start that organ again by applying a series of smart taps over the chest. The treatment should also be accompanied by drawing the arms in and out, so as to aid, or rather force artificial respiration. A number of authorities also advocate hypodermic injections of ether and alcohol beneath the skin, so as to distend the arteries, and help the heart action. In trying to disengage a man who is in contact with live metals, it is well to remember that dry clothing is a good insulator, and the best plan is to seize the victim's arm on the clothing and try to pull him away. Under no circumstances should the rescuer touch the bare skin, or take hold under the armpits where the clothing is apt to be damp.

SUGGESTIONS FOR RESUSCITATION FROM APPARENT DEATH FROM ACCIDENTAL ELECTRIC SHOCKS.

Augustin H. Goelet, M. D., in The Electrical World: The urgent necessity for prompt and persistent efforts at resuscitation of victims of accidental shocks by electricity is very well emphasized by the successful results in the few instances recorded. In order that the task may not be undertaken in a half-hearted manner, it must be appreciated that accidental shocks seldom result in absolute death, unless the victim is left unaided

for too long a time, or efforts at resuscitation are suspended too early.

In the majority of instances the shock is only sufficient to suspend animation temporarily, owing to the momentary and imperfect contact of the conductors, and also on account of the indifferent parts of the body submitted to the influence of the current. It must be appreciated also that the body under the conditions of accidental shocks seldom receives the full force of the current in the circuit, but only a shunt current, which may represent a very insignificant part of it. When an accident of this nature occurs, the following rules should be promptly adopted and executed, with due care and deliberation:

1. Remove the body at once from the circuit by breaking contact with the conductors. This may be accomplished by using a dry stick of wood (which is a non-conductor), to roll the body over to one side, or to brush aside a wire, if that is conveying the current. When a stick is not at hand, any piece of dry clothing may be utilized to protect the hand in seizing the body of the victim, unless rubber gloves are convenient. If the body is in contact with the earth, the coattails of the victim may be seized with impunity to draw it away from the conductor. When this has been accomplished, observe Rule 2.

2. Turn the body upon the back, loosen the collar and clothing about the neck, roll up a coat and place it under the shoulders, so as to throw the head back, and then make efforts to establish artificial respiration (in other words, make him breathe), just as would be done in case of drowning. To accomplish this, kneel at the subject's head, facing him and seizing both arms, draw

them forcibly to their full length over the head, so as to bring them almost together above it, and hold them there for two or three seconds only. (This is to expand the chest and favor the entrance of air into the lungs.) Then carry the arms down to the sides and front of the chest, firmly compressing the chest walls, and expel the air from the lungs. Repeat this maneuver at least sixteen times per minute. These efforts should be continued unremittingly for at least an hour, or until natural respiration is established.

3. At the same time that this is being done, some one should grasp the tongue of the subject with a handkerchief or piece of cloth to prevent it slipping, and draw it forcibly out when the arms are extended above the head, and allow it to recede when the chest is compressed. This maneuver should likewise be repeated at least sixteen times per minute. This serves the double purpose of freeing the throat so as to permit air to enter the lungs, and also, by exciting a reflex irritation from forcible contact of the under part of the tongue against the lower teeth, frequently stimulates an involuntary effort at respiration. If the teeth are clenched and the mouth cannot be readily opened to secure the tongue, force it open with a stick, a piece of wood, or the handle of a pocket knife.

While this is being done a physician should be summoned, who, upon his arrival, can best put into practice Rules 4 and 5 in addition to the foregoing, should it be necessary.

4. Forcible stretching the sphincter muscle controlling the lower bowel excites powerful reflex irritation and stimulates a gasp (inspiration) frequently when other measures have failed. For this purpose the sub-

ject should be turned on the side, the middle and index fingers inserted into the rectum, and muscles suddenly and forcibly drawn backward toward the spine. Or, if it is desirable to continue efforts at artificial respiration, at the same time the knees should be drawn up and the thumb inserted for the same purpose, the subject meanwhile retaining the position on the back.

5. Oxygen gas, which may be readily obtained at a drug store, if the accident occurs in a city or large town, is a powerful stimulant to the heart if it can be made to enter the lungs. A cone may be improvised from a piece of stiff paper and attached to the tube leading from the tank, and placed over the mouth and nose, while the gas is turned on during the efforts at artificial respiration.

It is both useless and unwise to attempt to administer stimulants to the victim in the usual manner by pouring it down his throat, therefore this should not be attempted.

GENERAL WIRING FORMULAE.

FROM GENERAL ELECTRIC CO. FOR "STANDARD WIRING."

The following general formulæ may be used to determine the size of conductors, volts lost in the line, and current per conductor for any system of electrical distribution:

$$\text{Area of conductor, Circular Mils} = \frac{D \times W}{P \times E^2} \times K.$$

$$\text{Volts loss in line} = \frac{P \times E}{100} \times M.$$

$$\text{Current in main conductors} = \frac{W}{E} \times T.$$

D=Distance of transmission (one way), in feet.

W=Total watts delivered to consumer.

P=Per cent. loss in line of *W*.

E=Voltage between main conductors at receiving or consumers' end of circuit.

K=2160 for continuous current.

K=2400 for single-phase, all lights.

K=3000 for single-phase, motors and lights.

K=3380 for single-phase, all motors.

K=1200 for three-wire three-phase and four-wire two-phase, all lights.

K=1500 for three-wire three-phase and four-wire two-phase, motors and lights.

K=1690 for three-wire three-phase and four-wire two-phase, all motors.

M=A variable depending on the size of wire and frequency used, and equal to 1 for continuous current.

T=A variable depending on the system and nature of the load, and equal to 1 for continuous current.

TABLE SHOWING THE CURRENTS WHICH WILL FUSE WIRES OF DIFFERENT SUBSTANCES

B. & S. Gauge.	Diam.	Copper.	Aluminum.	German Silver.	Iron.
10	102.	333.	246.5	170.	102.3
12	81.	236.	174.4	120.5	72.6
14	64.	165.7	122.8	84.6	50.9
16	51.	117.7	87.1	60.1	36.1
18	40.	81.9	60.7	41.8	25.2
20	32.	58.5	43.4	29.9	18.
22	25.3	41.1	30.5	21.0	12.4
24	20.	28.9	21.5	14.8	8.9
26	16.	20.7	15.3	10.6	6.4
28	12.6	14.5	10.7	7.4	4.5
30	10.	10.2	7.6	5.2	3.1
32	8.	7.3	5.4	3.7	2.3
34	6.3	5.1	3.8	2.6	1.6
36	5.	3.6	2.7	1.8	1.1

Values of the constant K for any particular power-factor are obtained by dividing 2160 by the square of that power-factor for single-phase, and by twice the square of that power-factor for three-wire three-phase, or four-wire, two-phase.

The resistance of line wire is taken as 10.8 ohms per mil foot.

CARRYING CAPACITIES AND DIMENSIONS OF WIRES AND CABLES.

Gauge No., B. & S.	Diameter, Mils.	Area Circular, Mils.	No. Amperes, Open Work.	No. Amperes, Concealed Work.	Ohms Per 1000 Ft.	Lbs. Per 1000 Ft. Bare.	Lbs. per 1000 Ft. Insulated.	No. and Size of Wires for Cables.
18.....	40	1,624	5	3	6.3880	4.92	18	
17.....	45	2,048	6	4	5.0660	6.20	21	
16.....	51	2,583	8	6	4.0176	7.82	25	
15.....	57	3,257	10	8	3.1860	9.86	31	
14.....	64	4,106	16	12	2.5266	12.44	38	
13.....	72	5,178	19	14	2.0037	15.68	43	
12.....	81	6,530	23	17	1.5890	19.77	48	
11.....	91	8,234	27	21	1.2602	24.93	64	
10.....	102	10,380	32	25	.99948	31.44	80	
9.....	114	13,090	39	29	.79242	39.65	97	
8.....	128	16,510	46	33	.62849	49.99	116	
7.....	144	20,820	56	39	.49845	63.03	118	
6.....	162	26,250	65	45	.39528	79.49	166	
5.....	182	33,100	77	53	.31346	100.23	196	
4.....	204	41,740	92	63	.24858	126.40	228	
3.....	229	52,630	110	75	.19714	159.38	265	
2.....	258	66,370	131	88	.15633	200.98	296	
1.....	289	83,690	156	105	.12398	253.43	329	
0.....	325	105,600	185	125	.09827	319.74	421	
00.....	365	133,100	220	150	.07797	402.97	528	
000.....	410	167,800	262	181	.06134	508.12	643	
0000.....	460	211,600	312	218	.04904	640.73	815	
Cables...	630	300,000	405	273	.03355	932		37-090
" ...	727.3	400,000	503	332	.02516	1242		37-1039
" ...	814.5	500,000	595	390	.02013	1553		61-0905
" ...	891.9	600,000	682	440	.01666	1863		61-0991
" ...	963.9	700,000	765	488	.01438	2174		61-1071
" ...	1030.5	800,000	846	540	.01258	2474		61-1145
" ...	1092.6	900,000	924	585	.01118	2795		61-1214
" ...	1152	1,000,000	1000	630	.01006	3106		61-128
" ...	1208.7	1,100,000	1075	675	.00915	3416		61-1343
" ...	1262.8	1,200,000	1147	715	.00838	3727		91-1148
" ...	1314.5	1,300,000	1217	755	.00769	4038		91-1195
" ...	1364	1,400,000	1287	795	.00715	4348		91-124
" ...	1413.5	1,500,000	1356	835	.00667	4658		91-1285
" ...	1458 6	1,600,000	1423	875	.00625	4968		91-1326
" ...	1503.7	1,700,000	1489	910	.00588	5278		91-1367
" ...	1547.7	1,800,000	1554	945	.00556	5588		127-1195
" ...	1571.9	1,900,000	1618	980	.00527	5898		127 1223
" ...	1630.2	2,000,000	1681	1015	.00500	6208		127-1554

Weight of insulation on cables varies for different kinds of work.

TABLE OF DIMENSIONS AND RESISTANCES OF COPPER WIRE.

Gauge No.	Diam. Mils.	Area. Circ. Mils. B. & S. Gauge.	BARE WIRE.			UNDERWRITERS' WIRE.		
			Lbs. per 1000 ft.	Lbs. per Mile.	Ft. per Pound.	Lbs. per 1000 ft.	Lbs. per Mile.	Ft. per Pound.
0000	460.	211600.	640.73	3383.04	1.56	860	4224.	1.25
000	410.	167800.	508.12	2682.85	1.97	666	3516.	1.50
00	365.	133100.	402.97	2127.66	2.48	500	2640.	2.00
0	325.	105600.	319.74	1688.20	3.13	363	1917.	2.75
1	289.	83690.	253.43	1338.10	3.95	313	1653.	3.20
2	258.	66370.	200.98	1061.17	4.98	250	1320.	4.00
3	229.	52630.	159.38	841.50	6.28	200	1056.	5.00
4	204.	41740.	126.40	667.38	7.91	144	760.	6.9
5	182.	33100.	100.23	529.23	9.98	125	660.	8.0
6	162.	26250.	79.49	419.69	12.58	105	554.	9.5
7	144.	20820.	63.03	332.82	15.86	87	364.	11.5
8	128.	16510.	49.99	263.96	20.00	69	301.	14.5
9	114.	13090.	39.65	209.35	25.22			
10	102.	10380.	31.44	165.98	31.81	50	264.	20.0
11	91.	8234.	24.93	131.65	40.11			
12	81.	6530.	19.77	104.40	50.58	31	164.	32.0
13	72.	5178.	15.68	82.792	63.78			
14	64.	4106.	12.44	65.658	80.42	22	116.	45.0
15	57.	3257.	9.86	52.069	101.40			
16	51.	2583.	7.82	41.292	127.87	14	74.	70.0
17	45.	2048.	6.20	32.746	161.24			
18	40.	1624.	4.92	25.970	203.31	11	58.	90.0
19	36.	1288.	3.90	20.594	256.39			
20	32.	1021.	3.09	16.331	323.32			

The value of K for any particular power factor is obtained by dividing 2160, the value for continuous current, by the square of that power-factor for single-phase, and by twice the square of that power-factor for three-wire three-phase, or four-wire two-phase.

The value of M depends on the size of the wire, frequency, and power factor. It is equal to 1 for continuous current, and for alternating current with 100 per cent., power-factor, and sizes of wire given in the table of wiring constants.

The figures given are for wires 18 inches apart and are sufficiently accurate for all practical purposes, provided the displacement in phase between current and E.M.F. at the receiving end is not very much greater than that at the generator; in other words, provided that the reactance of the line is not excessive, or the line loss unusually high. For example, the constants should not be applied at 125 cycles if the largest conductors are used and the loss 20 per cent, or more of the power delivered. At lower frequencies, however, the constants are reasonably correct, even under such extreme conditions. They represent about the true values at 10 per cent. line loss, are close enough at all losses less than 10 per cent., and often, at least for frequencies up to 40 cycles, close enough for even much larger losses. Where the conductors of a circuit are nearer each other than 18 inches, the volts loss will be less than given by the formulæ, and if close together, as with multiple conductor cable, the loss will be only that due to resistance.

The value of T depends on the system and power-factor. It is equal to 1 for continuous current, and for single-phase current of 100 per cent. power-factor.

The value of A and the weights of the wires in the table are based on .00000302 lb. as the weight of a foot of copper wire of one circular mil area.

In using the formulæ and constants, it should be particularly observed that P stands for the per cent. loss in the line of delivered power, not for the per cent. loss in the line of the power at the generator; and that E is the potential at the end of the line, and not at the generator.

When the power factor cannot be more accurately determined, it may be assumed to be as follows for any alternating system operating under average conditions: Lighting with no motors, 95 per cent., lighting and motors together, 85 per cent.; motors alone, 80 per cent.

In continuous current three-wire systems, the neutral wire for feeders should be made of one-third the section obtained by the formulæ for either of the outside wires. In both continuous and alternating current systems, the neutral conductor for secondary mains and house-wiring should be taken as large as the other conductors.

When both motors and lights are used on the Monocyclic System, the primary circuit should be figured as if all the power was transmitted over the outside wires, and the size of the power wire should be in the proportion to either outside wire, as the motor load in amperes is to the total load in amperes. Secondary wires leading directly to induction motors on the Monocyclic System should all be of the same size as for a single-phase circuit of the same kilowatt capacity and power factor. The three wires of a three-phase circuit and the four wires of a two-phase circuit should all be made the same size, and each conductor should be of the cross-section given by the first formulæ.

WIRING CONSTANTS.

No. of Wire, B. & S. Gauge.	Area Circular Mils.	Weight of Bare Wire per 1000 ft. Pounds.	Values of M.								
			30 Cycles.			60 Cycles.			125 Cycles.		
			Lighting Only, 95 per cent P. F.	Motors and Lights, 85 per cent P. F.	Motors Only, 80 per cent P. F.	Lighting Only, 95 per cent P. F.	Motors and Lights, 85 per cent P. F.	Motors Only, 80 per cent P. F.	Lighting Only, 95 per cent P. F.	Motors and Lights, 85 per cent P. F.	Motors Only, 80 per cent P. F.
0000	211,600	640.73	1.26	1.27	1.24	1.64	1.85	1.85	2.44	3.06	3.14
000	167,805	508.12	1.20	1.17	1.14	1.49	1.63	1.62	2.15	2.62	2.67
00	133,079	402.97	1.15	1.08	1.05	1.39	1.46	1.42	1.92	2.25	2.29
0	105,592	319.74	1.10	1.00	1.00	1.30	1.32	1.28	1.73	1.96	1.99
1	83,694	253.43	1.06	1.00	1.00	1.23	1.21	1.16	1.57	1.74	1.73
2	66,373	200.98	1.03	1.00	1.00	1.16	1.11	1.06	1.44	1.54	1.53
3	52,633	159.38	1.02	1.00	1.00	1.11	1.04	1.00	1.35	1.38	1.38
4	41,742	126.40	1.00	1.00	1.00	1.07	1.00	1.00	1.26	1.26	1.22
5	33,102	100.23	1.00	1.00	1.00	1.04	1.00	1.00	1.19	1.16	1.11
6	26,250	79.49	1.00	1.00	1.00	1.02	1.00	1.00	1.14	1.08	1.03
7	20,816	63.03	1.00	1.00	1.00	1.00	1.00	1.00	1.09	1.01	1.00
8	16,509	49.99	1.00	1.00	1.00	1.00	1.00	1.00	1.06	1.00	1.00

WIRING CONSTANTS.

Values of T.	
Single-phase, all lights. 95 per cent P. F.	1.052
Single-phase, motors and lights. 85 per cent P. F.	1.176
Single-phase, all motors. 80 per cent P. F.	1.250
Three-phase, all lights. 95 per cent P. F.	.607
Three-phase, motors and lights. 85 per cent P. F.	.679
Three-phase, all motors. 80 per cent P. F.	.725
Two-phase (four-wire), all lights. 95 per cent P. F.	.526
Two-phase (four-wire), motors and lights. 85 per cent P. F.	.588
Two-phase (four-wire), all motors. 80 per cent P. F.	.625

System.	Values of A.	Values of K. Per Cent. Power Factor.				Values of T. Per Cent. Power Factor.				
		100	95	90	85	80	100	95	90	85	80
Single-phase	6.04	2160	2400	2660	3000	3350	1.00	1.05	1.11	1.17	1.25
Two-phase (four-wire)	12.08	1080	1200	1330	1500	1690	.50	.53	.55	.59	.63
Three-phase (three-wire)	9.06	1080	1200	1330	1500	1690	.58	.61	.64	.68	.72

No. of Wire, B. & S. Gauge.	Area Wire, Circular Mils.	Weight of Bare Wire Per 1000 Feet, Pounds.	Resistance of Wire Per 1000 Feet at 20° C. Ohms.	Values of M. for Wires 18 inches apart C. to C.															
				25 Cycles.				40 Cycles.				60 Cycles.				125 Cycles.			
				Per Cent. Power Factor.				Per Cent. Power Factor.				Per Cent. Power Factor.				Per Cent. Power Factor.			
				95	90	85	80	95	90	85	80	95	90	85	80	95	90	85	80
0000	211,600	640.73	.04879	1.23	1.29	1.33	1.34	1.52	1.53	1.61	1.67	1.62	1.84	1.99	2.09	2.35	2.86	3.24	3.49
000	167,805	508.12	.07154	1.18	1.22	1.24	1.24	1.40	1.41	1.48	1.51	1.49	1.66	1.77	1.95	2.08	2.48	2.77	2.94
00	133,079	402.97	.07758	1.14	1.16	1.16	1.16	1.25	1.32	1.35	1.37	1.34	1.52	1.60	1.66	1.86	2.18	2.40	2.57
0	105,560	319.00	.09775	1.10	1.11	1.10	1.09	1.19	1.24	1.26	1.26	1.31	1.40	1.46	1.49	1.71	1.96	2.13	2.25
1	83,694	253.43	.1234	1.07	1.07	1.05	1.03	1.14	1.17	1.18	1.17	1.24	1.36	1.34	1.36	1.56	1.75	1.88	1.97
2	66,373	200.98	.1556	1.05	1.04	1.02	1.	1.11	1.12	1.12	1.10	1.18	1.23	1.25	1.26	1.45	1.60	1.70	1.77
3	52,633	159.38	.1962	1.03	1.02	1.	1.	1.07	1.08	1.07	1.05	1.14	1.17	1.18	1.17	1.35	1.46	1.53	1.57
4	41,742	126.40	.2473	1.02	1.	1.	1.	1.05	1.06	1.03	1.	1.11	1.12	1.11	1.10	1.27	1.35	1.40	1.43
5	33,102	100.23	.3120	1.	1.	1.	1.	1.03	1.01	1.	1.	1.08	1.08	1.06	1.04	1.21	1.27	1.30	1.31
6	26,250	79.49	.3934	1.	1.	1.	1.	1.02	1.	1.	1.	1.05	1.04	1.02	1.	1.16	1.20	1.21	1.21
7	20,816	63.03	.4958	1.	1.	1.	1.	1.01	1.	1.	1.	1.03	1.02	1.	1.	1.12	1.14	1.14	1.13
8	16,509	49.99	.6250	1.	1.	1.	1.	1.	1.	1.	1.	1.02	1.	1.	1.	1.09	1.10	1.09	1.07
9	13,090	39.6	.7886	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.06	1.06	1.04	1.02
10	10,382	31.4	.9940	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.04	1.03	1.	1.

FUSING EFFECTS OF CURRENTS.

Table giving the diameters of wires of various materials which will be fused by a current of given strength.

W. H. PREECE, F. R. S.

$$d=\left(\frac{C}{a}\right)^{\frac{2}{3}}$$

Current in amperes.	DIAMETERS IN INCHES								
	Copper, a=10 244	Aluminum, a=7 585	Platinum, a=5 172	German Silver, a=5 230	Platinoid, a=4 750	Iron, a=3 148	Tin, a=1 642	Tin-lead alloy, a=1 318	Lead, a=1 379
1	.0021	.0026	.0033	.0033	.0035	.0047	.0072	.0083	.0081
2	.0034	.0041	.0053	.0053	.0056	.0074	.0113	.0132	.0128
3	.0044	.0054	.007	.0069	.0074	.0097	.0149	.0173	.0168
4	.0053	.0065	.0084	.0084	.0089	.0117	.0181	.021	.0203
5	.0062	.0076	.0098	.0097	.0104	.0136	.021	.0243	.0236
10	.0098	.012	.0155	.0154	.0164	.0216	.0334	.0386	.0375
15	.0129	.0158	.0203	.0202	.0215	.0283	.0437	.0506	.0491
20	.0156	.0191	.0246	.0245	.0261	.0343	.0529	.0613	.0595
25	.0181	.0222	.0286	.0284	.0303	.0398	.0614	.0711	.069
30	.0205	.025	.0323	.032	.0342	.045	.0694	.0803	.0779
35	.0227	.0277	.0358	.0356	.0379	.0498	.0769	.089	.0864
40	.0248	.0303	.0391	.0388	.0414	.0545	.084	.0973	.0944
45	.0268	.0328	.0423	.042	.0448	.0589	.0909	.1052	.1021
50	.0288	.0352	.0454	.045	.048	.0632	.0975	.1129	.1095
60	.0325	.0397	.0513	.0509	.0542	.0714	.1101	.1275	.1237
70	.036	.044	.0568	.0564	.0601	.0791	.122	.1413	.1371
80	.0394	.0481	.0621	.0616	.0657	.0864	.1334	.1544	.1499
90	.0426	.052	.0672	.0667	.0711	.0935	.1443	.1671	.1621
100	.0457	.0558	.072	.0715	.0762	.1003	.1548	.1792	.1739
120	.0516	.063	.0814	.0808	.0861	.1133	.1748	.2024	.1964
140	.0572	.0698	.0902	.0895	.0954	.1255	.1937	.2243	.2176
160	.0625	.0763	.0986	.0978	.1043	.1372	.2118	.2452	.2379
180	.0676	.0826	.1066	.1058	.1128	.1484	.2291	.2652	.2573
200	.0725	.0886	.1144	.1135	.121	.1592	.2457	.2845	.276
225	.0784	.0958	.1237	.1228	.1309	.1722	.2658	.3077	.2986
250	.0841	.1028	.1327	.1317	.1404	.1848	.2851	.3301	.3203
275	.0897	.1095	.1414	.1404	.1497	.1969	.3038	.3518	.3417
300	.095	.1161	.1498	.1487	.1586	.2086	.322	.3728	.3617

The following tables show the minimum break distance, and the separation of the nearest metal parts of opposite polarity for plain open-link fuses and switches, when mounted on slate or marble bases, for different voltages and for different currents:

	Separation of nearest metal parts of opposite polarity.	Minimum break distance.
125 VOLTS OR LESS.		
10 amperes or less	¾ inch	¾ inch
11-100 amperes	1 "	¾ "
101-300 amperes	1 "	1 "
125 TO 250 VOLTS.		
10 amperes or less	1½ "	1¼ "
11-100 amperes	1¾ "	1¼ "
101-300 amperes	2 "	1½ "
125 VOLTS OR LESS.		
FOR SWITCH AND PANEL BOARDS:		
10 amperes or less	¾ "	½ "
11-25 amperes	1 "	¾ "
26-50 amperes	1¼ "	1 "
FOR INDIVIDUAL SWITCHES:		
10 amperes or less	1 "	¾ "
11-25 amperes	1¼ "	1 "
36-100 amperes	1½ "	1¼ "
101-300 amperes	2¼ "	2 "
301-1000 amperes	3 "	2¾ "
125 TO 250 VOLTS.		
FOR ALL SWITCHES:		
10 amperes or less	1½ "	1¼ "
11-35 amperes	1¾ "	1½ "
36-100 amperes	2¼ "	2 "
101-300 amperes	2½ "	2¼ "
301-1000 amperes	3 "	2¾ "
250 TO 600 VOLTS.		
FOR ALL SWITCHES:		
10 amperes or less	3½ "	3 "
10-35 amperes	4 "	3½ "
36-100 amperes	4½ "	4 "

Auxiliary breaks or equivalents are recommended for switches designed for over 300 volts, and less than 100 amperes, and are required on switches designed for use in breaking currents over 100 amperes, at a pressure of more than 300 volts.

AMPERES PER MOTOR.

G. CUTTER.

H. P.	Per Cent.	Watts.	The Top Row Indicates Volts.								
			50	75	110	220	400	500	600	800	1000
¾	75	746	14.9	9.94	6.79	3.38	1.86	1.48	1.24	.93	.746
1½	75	1492	29.8	19.8	13.56	6.78	3.73	2.98	2.48	1.86	1.492
3	80	2797	55.9	37.2	25.4	12.7	6.99	5.59	4.66	3.49	2.797
5	80	4662	93.2	62.1	42.3	21.1	11.65	9.32	7.77	5.82	4.662
7½	90	6217	124.	82.9	56.5	28.2	15.54	12.43	10.36	7.77	6.217
10	90	8288	165.	110.	75.5	37.6	20.72	16.57	13.81	10.36	8.288
15	90	12433	248.	165.	113.	56.5	31.08	24.86	20.72	15.53	12.43
20	90	16578	331.	221.	150.	75.3	41.44	33.15	27.63	20.72	16.57
25	90	20722	414.	276.	188.	94.1	51.8	41.6	34.5	25.9	20.7
30	90	24866	497.	331.	226.	113.	62.	49.7	41.4	31.	24.8
40	90	33155	663.	442.	301.	150.	82.8	66.3	55.2	41.4	33.1
50	90	41444	828.	552.	376.	188.	103.	82.8	69.	51.8	41.4
60	90	49733	994.	663.	452.	226.	124.	99.4	82.8	62.	49.7
70	90	58022	1160.	773.	527.	263.	145.	116.	96.7	72.5	58.
80	90	66311	1326.	884.	602.	301.	165.	132.	110.	82.9	66.3
90	90	74599	1491.	994.	678.	339.	186.	149.	124.	93.	74.5
100	90	82888	1657.	1105.	753.	376.	207.	165.	138.	103.	82.8
120	90	99457	1989.	1326.	904.	452.	248.	198.	165.	124.	99.
150	90	124312	2486.	1657.	1131.	565.	310.	248.	207.	155.	124.

PRINCIPLES GOVERNING THE ACTION OF BRAKES.

When the brake is applied the energy stored in the moving car by the motors is consumed, being overcome by the friction of the brake shoes against the wheels.

The efficient application of the brake, with a view to stop the car within the least possible distance, with the least strain and wear upon equipment, and shock to passengers, is primarily a matter of good judgment, coupled with experience. Therefore, the study of the brake and braking apparatus in its completeness will largely add to the value of the motorman, to his company, for the saving of power alone which can be effected by an intelligent operation of the brakes is an item of no small consequence in the economy of operating electric cars. Together with their various modifications there are five principal styles of brakes in general use.

1. The earliest style of brake is the hand brake; the brake shoes being pressed against the wheels with power supplied by the physical force of the motorman, and either by means of a long lever or by staff upon which a chain is wound by turning.

2. The momentum or disc brake is operated through the medium of a friction disc, or clutch mounted on the axle, and the brake shoe is drawn up by the power which the momentum of the car provides.

3. The air brake, which is operated by compressed air power, pressing the shoe against the wheel by means of a piston which works in and out of the cylinder containing the compressed air.

4. The electric brake is operated by the motors themselves, which are connected to act as dynamos and furnish the electricity which exerts the force that stops, as well as starts, and runs the car.

5. Track brakes absorb the energy expressed in the momentum of the car, by friction against the rail instead of the car wheel. The shoes adjusted to a part of the braking apparatus are carried at the sides of the truck, and press down upon the top of track rail with force enough to check the movement of the car.

In modern electric railway operation nearly all cars are equipped with power brakes of some kind, in addition to hand brakes. These cars are equipped with mechanism consisting of different combinations of rods, beams, and levers, and by the manipulation of the brake levers or handles the power is transmitted through the system, causing a pressure of the brake shoe against the wheels with varying degrees of force at the discretion of the operator.

The general principle applying in the arrangement of the many styles of brake rigging with which trucks are provided is the same; the differences consisting of detail, rather than of essential variations. In an ordinary truck equipped with hand brakes, the brake shoes are located close behind the car wheels.

When the brakes are not set there is a space of about ⅛ in. between the brake shoes and the wheels. The shoes are adjusted to the brake beams, and to the latter, one end of the brake rod is attached, and the other end is made fast to the cross beam, which engages with the equalizer bar. The hook rods, into which the brake chain is hooked, are secured at the ends of the equalizer

bar. When the brake is released the brake shoes are removed from the wheels by means of a strong spring.

When the brake handle is turned around one or more turns the brake chain is wound up, and the hook rod is pulled forward which moves the equalizer bar, and thereby the cross beams. When the cross beams move toward each other the rods are moved, which brings the brake beams and shoes towards each other, fixing the brake shoes firmly against the wheels. As all of the brake shoes act at the same time, in course of time the wear on some of the shoes will be greater than on others, thus causing slack. To provide against the effect of slack an adjustment is made to take up the slack, and this is done where the rods connect with the brake beam near the shoes. The ends of the rods are threaded, and in pockets provided in the brake beam nuts are secured. Into these sleeve nuts the rods are screwed. To make the adjustment the head of the nut is turned, which shortens the rod, and brings a worn shoe nearer to the wheel. By this method each shoe can be adjusted separately as may be required, and the pressure of every shoe maintained at normal pressure.

The brake mechanism on double-truck cars is modified in order that means may be provided to obtain an approximately equal pressure on every wheel, which insures maximum braking effect and prevents sliding, which would occur if one set of wheels were locked more firmly than the others. In order to apply the brakes on both trucks by one motion of the single brake handle, or by one air brake cylinder, there is introduced a fixed lever in the center of the car between the trucks, and to this are connected the brake rods from each truck. By means of a chain and rod, the central lever is connected

to the brake staff, and the brakes of both trucks can be operated simultaneously by moving the rod and central lever.

The dimensions of the levers are given below:

Fixed Lever, length 48 ins. Distance between the pins for the arch bar rod 9 ins.

Truck Lever, length 13 ins.

Brake Handle, length 15 ins.

Exerting a pull of 65 lbs. at the brake handle with these dimensions will produce a total braking pressure of 29,000 lbs.

On these brakes there are chains in duplicate, working with a double sprocket wheel instead of one chain wound around the brake staff. If one chain breaks the other may be brought into action and the operator can, when applying the brakes, feel the slightest contact of the brake shoes with the wheels.

NEW AIR BRAKE EQUIPMENTS FOR STEAM RAILROADS—LATEST DEVICES OF THE NEW YORK AIR BRAKE CO. AND THE WESTINGHOUSE CO.

On account of the constantly increasing demand from our students for information concerning the new equipments, and the latest appliances connected with the air brake, as applied to steam railroads, it has been thought best to introduce at this point a section giving full and complete descriptions, and illustrations of the very latest improved devices, as applied by both the Westinghouse and New York Air Brake companies. Among the many new equipments described will be included the B^2 H. S. and B^2 H. P. equipment, the Duplex pressure controller, and double pressure system; the acceleration valve and high speed controller of the New York system. The new E. T. equipment of the Westinghouse system is clearly described and illustrated, including the new distributing valve, the type H brake valve, the independent brake valve, type K freight valve, and type L triple valve. The construction and operation of each and all of these latest improved devices is placed before the student in a plain, practical manner, and a close study of the principles governing their action cannot fail to be of great benefit to the man engaged in railroad practice, whether steam or electric.

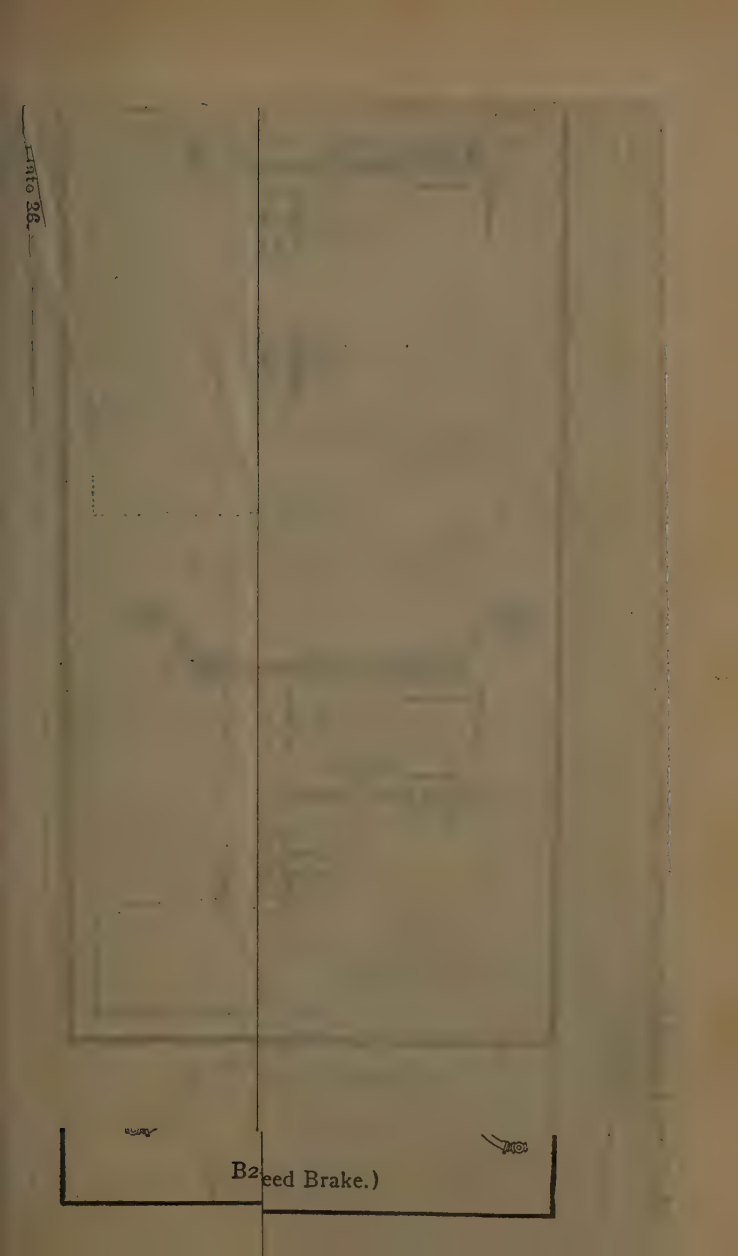


Plate 26.
B2eed Brake.)

The accelerator valve will be found a valuable addition to these equipments when operating long trains, for, with the use of same, shorter stops will be effected, and a more uniform application of the train brakes obtained.

All excess pressure is confined to the main reservoir, and in no position of the brake valve handle can the brake pipe pressure increase above its maximum. This will prevent over-charging of auxiliary reservoirs on the head end of trains, and also reduce the strain on air brake hose.

B2 EQUIPMENT.

This equipment is designed for passenger or freight service where but one brake pipe pressure is used.

Both pump governor and pressure controller have single regulating heads. The pressure head for the pressure controller should be adjusted to 70 lbs. for brake pipe pressure, and the pump governor head adjusted to 90 lbs. for main reservoir pressure.

B2-S EQUIPMENT.

This equipment is for use with switch engines as before stated. A single pump governor is provided, also a single pressure controller for brake pipe pressure regulation. In the pipe connecting the regulating and supply portions of the pressure controller is located cut-out cock No. 2. When this cock is open the controller should give a maximum brake pipe pressure of 70 lbs. and the pump governor adjusted to 110 lbs. for main reservoir pressure. This will give the necessary air pressure for freight service. By closing the cut-out cock the pressure

controller will become inoperative, allowing the main reservoir pressure of 110 lbs. to pass to the brake valve, and brake pipe for high speed service.

B2-HP EQUIPMENT.

This equipment is for use in freight service only. Both regulating portions of the pump governor and pressure controller are duplex, so that pressures of 70 and 90 lbs. can be carried in the brake pipe and 90 and 110 lbs. in the main reservoir for the ordinary brake pipe pressure and the high pressure control.

For the operation of these duplex regulating portions, three way cocks are provided, being connected as shown in the piping diagram.

To operate these cocks turn the handle in line with the pipe leading to the regulating head to be used, high or low pressure as desired. This will cut in the head to regulate the supply portion, and cut off the one not in use.

B2-HS EQUIPMENT.

High speed locomotive brake equipment. The system of regulation of pressure for the high speed equipment is the same as with the B2-HP except that the regulating heads of the pressure controller should be adjusted to 70 and 110 lbs. for brake pipe pressure, and the pump governor heads adjusted to 90 and 120 or 130 lbs. as desired for main reservoir pressure.

MANIPULATION.

On the folded sheet (Plate 36) will be found piping diagrams of the several B-2 equipments, and it should be referred to in connection with the following instructions:

GENERAL.

To apply the locomotive and train brakes (automatic), move the handle of the brake valve to the graduating notch necessary to make the required brake pipe reduction.

To release both locomotive and train brakes, move the handle to Running and Straight Air release position.

To release the train brakes and hold the locomotive brakes set (Straight Air), move the handle to Full Automatic release and Straight Air application position.

To release the locomotive brakes, move the handle to Running and Straight Air release position.

To apply the locomotive brakes (Straight Air), move the handle to Full Automatic release and Straight Air application position.

To apply the brakes in an emergency, move the handle quickly to Emergency position, and leave it there until the train stops, or the danger has passed.

In case the automatic brakes are applied by the bursting of a hose, the train parts, or a conductor's valve is opened, place the handle in Lap position to retain the main reservoir pressure.

To graduate off or entirely release the locomotive brakes after an application of the train brakes, use the lever safety valve to make the required reduction.

The handle of the brake valve will be found to work freely and easily at all times, as the pressure on the main slide valve does not exceed the maximum brake pipe pressure.

The cylinder gauge will show at all times the pressure in the locomotive brake cylinders, and should be observed in all brake manipulations.

Where there are two or more locomotives in a train cut-out cock No. 1, shown in plate 36, should be turned to close the brake pipe, and the brake valve handle carried in Running and Straight Air release position on all locomotives, except the one from which the brakes are operated.

In case it becomes necessary to cut out the Straight Air brake, close cut-out cock No. 3 which is located in the straight air pipe between the Brake Valve and the Reducing Valve.

To cut out the Automatic Brake, close cut-out cock No. 6 located in the pipe connecting the Triple Valve with the Double Check Valve.

By locating the cut-out cock between the Triple and Double Check Valves, the auxiliary reservoirs will remain charged, while the brake is cut out, and can be alternated with the train brakes in descending long grades to prevent overheating of the locomotive tires.

Cut-out cocks Nos. 3 and 6 are special, they are of the three-way pattern, and when turned off drain the pipes leading to the double check valve to keep the latter seated in the direction of the closed cock.

The main reservoir cock No. 4 is to cut off the supply of air when removing any of the apparatus except the governor.

The straight air controller is to limit the pressure in

the driver, truck and tender brake cylinders for the straight air brake, and should be adjusted to 40 pounds pressure.

Cut-out cocks Nos. 5, 6 and 7 are recommended when truck brake is used, their purpose being fully understood. Nos. 9 and 10 can be added, if desired, so that the driver brake cylinders and reservoir can be cut out, and engine truck brake operated by truck brake reservoir.

THE B2 BRAKE VALVE.

This brake valve, although modeled somewhat upon the principles of the B and B1 valves, is necessarily different in detail so as to embody the features of the pressure controller and those of the united straight air. Fig. 266 is a photographic view of the valve. Fig. 267 is a

Fig. 266. B-2 Brake Valve.

longitudinal side section showing travel of main slide valve EV 194 and how the graduating valve EV 110 is controlled by the piston EV 193. This view also shows the different positions of the brake valve handle. Fig. 268 is a top view of the valve with the cover, slide valve

and handle removed, showing seat and connections for the straight air and divided reservoir pipes. Fig. 269 is a cross section through the valve (rear view). Fig. 270 is a cross section through the main slide valve. Fig. 271 shows the face of the main slide valve.

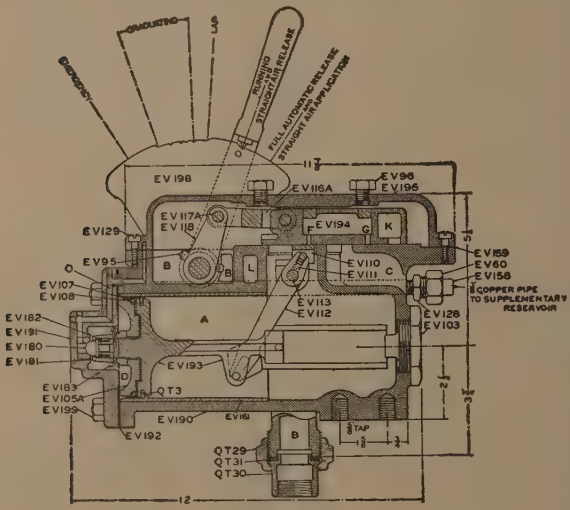


Fig. 267.

The main reservoir pipe is connected from the pressure controller to chamber B (Fig. 267) in the top of the valve. The brake pipe is connected to chamber A. Discharge of brake pipe air to the atmosphere for service applications occurs through ports F and G in the main slide valve and exhaust passage C in the valve body and for emergency applications through ports J and K in

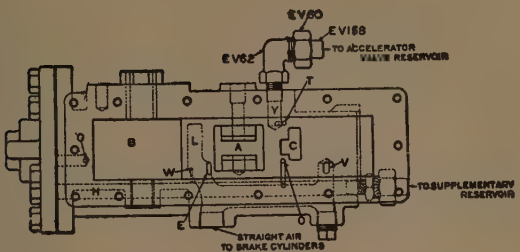


Fig. 268.

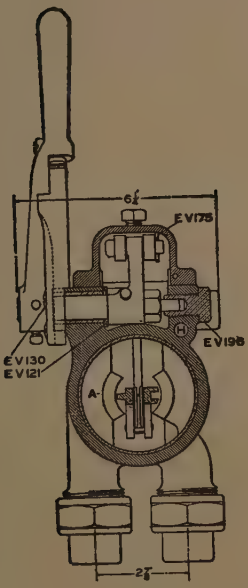


Fig. 269.

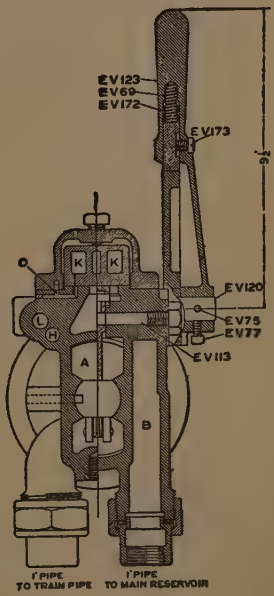


Fig. 270.

the slide valve (Fig. 271) and exhaust passage C. The main slide valve also controls the flow of air from the main reservoir to the brake pipe. In Full automatic release position air is free to pass from the main reservoir to the brake pipe through ports M and also around the slide valve, as in this position the slide valve is moved forward, uncovering a portion of the passage. (See Fig. 272.) When the handle is in Running position only ports M are open but are of a size to promptly release all train brakes. (See Fig. 273.)

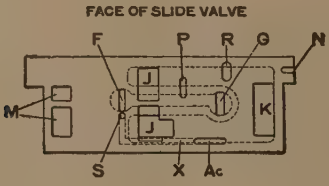


Fig. 271.

Small slide valve EV 110 is a cut-off or graduating valve, operated by piston EV 193, and lever EV 112. In service applications it automatically laps port F, and stops the discharge of brake pipe air when the brake pipe reduction, corresponding to the service graduating notch in which the handle is placed, has been made. Piston EV 193, which is exposed on one side to brake pipe pressure (Chamber A) and on the other to Chamber D, and supplementary reservoir pressure, through the agency of lever EV 112 causes valve EV 110 to move automatically whatever distance is necessary to close port F.

Passage H (Figs. 267 and 269) runs lengthwise to the valve, one end leading to the supplementary reservoir

as indicated in Fig. 267, while the other end leads to the space D, back of the piston EV 193. In Full automatic release, and in Running and Straight Air release positions, air from chamber B, Fig. 268, passes through port W to passage H and supplementary reservoir, until there is equal pressure on both sides of the piston EV 193 and the supplementary reservoir pressure is equal to the brake pipe pressure.

Fig. 272. Release Position.

Port O (Fig. 267), is used to return the piston EV 193 to its normal position when releasing the brakes, and is open to the exhaust passage C when the handle of the brake valve is in Full Automatic Release, Running, and Lap positions, and closes just before the handle is brought to the first graduating notch. During the time the brake valve handle is in any of these positions, port O is open through passage C to the atmosphere, as stated, and if it were not for the vent valve EV 180 the function of piston EV 193 would be destroyed, as a continual blow from chamber D would result while the piston EV 193 is in operation the vent valve EV 180 is away from its seat, thus opening port O to the slide valve

seat, to be opened when the handle is again returned to release position.

Connection is made with the straight air pipe through passage L (See Figs. 268 and 272) to which ports E and V connect from the main slide valve seat. Port E is the admission port and is open to receive pressure from chamber B when the handle of the brake valve is in Full automatic release and Straight Air application position. Port V is the exhaust port and is used to exhaust the pressure from the driver brake cylinders in releasing the straight air brake, the release being accomplished through ports R and J in the main slide valve, and passage C in the valve body. (See Fig. 273.)

Fig. 273. Running Position.

Port V is also used to pass pressure from chamber B to the straight air brake when the handle is in the Fifth graduating notch and Emergency position. This is done so that if there is cylinder leakage or excessive piston travel, the Straight Air brake will hold the pressure in these cylinders to the adjustment of the Reducing Valve.

In all graduating positions of the Brake Valve, brake pipe pressure is admitted to the divided reservoir (Large compartment Fig. 279) to operate the Accelerator Valve.

When the Brake Valve handle is moved to any of the graduating notches, brake pipe pressure will flow through port S, passage X, and cavity AC in the main slide valve (Fig. 271) and through port T, and passage Y in the Valve body (Fig. 268) to the divided reservoir until the port S is cut off by the Graduating Valve EV 110, when the latter closes the service port F. To guard against possibility of the Accelerator Valve being open while the Brake Valve handle is in a Release position, which might occur if the handle was returned before a service application had been completed, port J in the main slide valve (Fig. 271) has been enlarged so as to open port T to the exhaust passage C, and the atmosphere when the handle is in a release position. These ports are large enough to rapidly discharge the air accumulated in the divided reservoir, and thereby permit the accelerator valve to immediately close. By referring to the diagrammatic views of the main slide valve and seat shown in Figs. 272 to 277 inclusive, it will be seen what ports are open and closed in the different positions of the slide valve.

FULL AUTOMATIC RELEASE AND STRAIGHT AIR APPLICATION POSITION (FIG. 272).

The purpose of this position is to promptly release the automatic brakes and to apply the straight air brakes on the Locomotive. In this position, air is flowing directly from chamber B (main reservoir) into chamber A (brake pipe) past the end of the slide valve and through ports M. Port O is open to port J and exhaust passage C to return the piston EV 193, and port W is open to charge the supplementary reservoir. Port T, also by means of

port J, is open to the exhaust passage C to discharge the pressure from the large compartment of the divided reservoir. Port E is also open for pressure to pass to the driver brake cylinders through the straight air pipe until shut off by the reducing valve.

RUNNING POSITION.

Running and Straight Air Release Position. (Fig. 273.) This is the proper position of the handle when wishing to release both Straight Air and Automatic brakes simultaneously, or to release the Straight Air Brake. Connection from Chamber B into Chamber A

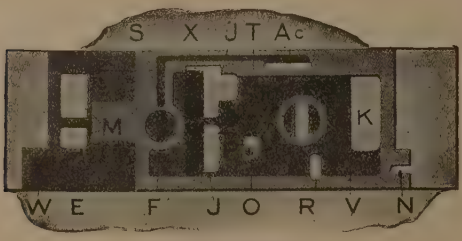


Fig. 274. Lap Position.

is made through the ports M. Port E is lapped. Ports O, T and W remain the same as in Release Position. Ports R and V register with each other, thus connecting the straight air brake with the exhaust passage C as shown, to discharge the pressure from the driver brake cylinders.

Lap Position. (Fig. 274.) This position should be used in case a hose bursts, the train parts or a conductor's valve is opened, to save the main reservoir pres-

sure. In this position all ports are blanked, excepting port O. As in Release and Running Positions, this port is open to the exhaust passage C. In this particular position cavity P in the slide valve seat is made use of to connect the port with passage C.

Fig. 275. First Graduating Position.

GRADUATING POSITIONS. (Figs 275 and 276.) These positions give a gradual reduction of brake pipe pressure for service applications. In Fig. 275 ports M are

Fig. 276. Last Graduating Position.

blanked and communication from the main reservoir to the brake pipe is cut off. The straight air ports E and V are also blanked, as well as ports O and W, which are cut off just before the handle reaches the First Graduat-

ing Notch. Ports F and G are open to the exhaust passage C, and port S is open through passage X to port T to receive pressure from the brake pipe and pass it to the divided reservoir to operate the Accelerator Valve. Ports F and S will remain open to receive brake pipe pressure until cut off by the graduating valve EV 110 when the service reduction has been made.

In the remainder of the Graduating Positions, the relation of ports remains the same with the exception of the restricted passage N (Fig 276) in the end of the slide valve which in the Fifth Graduating notch is over the straight air port V, and should there be excessive piston travel or cylinder leakage the Straight Air equipment will hold the pressure in these cylinders to the adjustment of the reducing valve. The restriction of port N is to prevent the pressure from passing to the driver brake cylinders in advance of pressure from the auxiliary reservoir of the automatic brake.

Fig. 277. Emergency Position.

EMERGENCY POSITION (FIG. 277).

This position is to be used when it is desired to apply the brakes to their quickest and fullest capacity. In this position, the active ports are J and K, which are open to exhaust brake pipe pressure from chamber A to the

atmosphere. Port V as in the fifth graduating notch is open to maintain the pressure in the driver brake cylinders against leakage, etc. Port E is closed, also ports F, M, O, S, T and W.

To dismantle the Valve, the valve cover EV 195 should first be removed, and then the back cap EV 191. The main slide valve EV 194 should be taken off, and the Graduating valve EV 110 lifted out—also the Graduating valve spring EV 111. Next remove the fulcrum pin EV 113, after which remove the piston EV 193.

Do not attempt to remove the follower cap nut EV 181 from the piston EV 193 while the piston is in the valve body, as to do this would probably result either in springing the groove in the piston stem, or in breaking off the dowel pin in the valve body.

Figs, 267 to 270 show the different parts of the valve, their names being as follows: EV 60, Small union nut; EV 62, Small union ell; EV 69, Handle spring; EV 75, Handle pin; EV 77, Handle set screw; EV 95, Lever shaft pin with cotter; EV 96, ¼" plug; EV 103, End plug; EV 105-A, Follower; EV 107, Packing Leather; EV 108, Expander; EV 110, Graduating Valve; EV 111, Graduating valve spring; EV 112, Graduating valve lever; EV 113, Fulcrum pin; EV 116-A, Link; EV 117-A Link pin; EV 118, Slide valve lever; EV 120, Lever shaft; EV 121, Lever shaft packing; EV 123, Handle; EV 128, Small union stud; EV 129, Cover screw; EV 130, Quadrant screw; EV 158, Small union swivel; EV 159, Cover gasket; EV 172, Latch; EV 173, Latch screw; EV 175, Link pin cotter; EV 180, Vent valve; EV 181, Follower cap nut; EV 182, Vent valve spring; EV 183, Piston cotter; EV 190, Body; EV 191, Back cap; EV 192, Cap gasket; EV 193, Piston; EV 194, Main slide valve;

EV 195, Valve cover; EV 196, Lever shaft plug; EV 198, Quadrant; EV 199, Back cap stud and nut; QT 3, Piston ring; QT 29, 1″ Union nut; QT 30, 1″ Union swivel; QT 31, 1″ Union gasket.

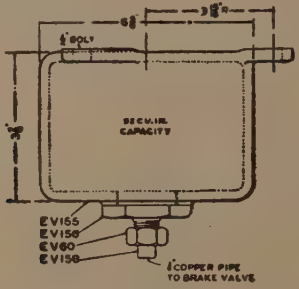


Fig. 278.

SUPPLEMENTARY RESERVOIR USED WITH SWITCH ENGINE EQUIPMENT, SCHEDULE B2-S (FIG. 278).

NAMES OF PARTS.

EV 60, Small union nut; EV 155, Supplementary reservoir; EV 156, Reservoir plug; EV 158, Union swivel (⅜″ copper pipe).

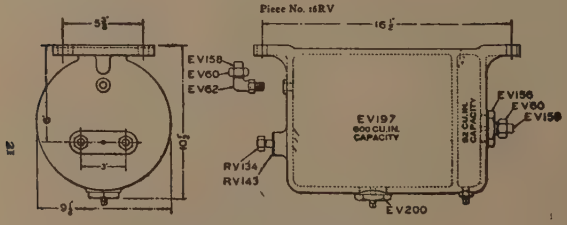


Fig. 279. Divided Reservoir.

E V 60—Small union nut.
E V 62—Small union ell.
E V 156—Reservoir plug.
E V 158—Union swivel.
E V 197—Divided reservoir.
E V 200—Botton plug.
R V 134—½-inch stud and nut.
R V 143—Accelerator valve gasket.

THE DUPLEX PRESSURE CONTROLLER AND DOUBLE PRESSURE SYSTEM.

This valve, in reality, is a part of the Brake Valve, taking place of the excess pressure or feed valve, and is connected in the main reservoir pipe near the Brake Valve, to control the brake pipe pressure. The Con-

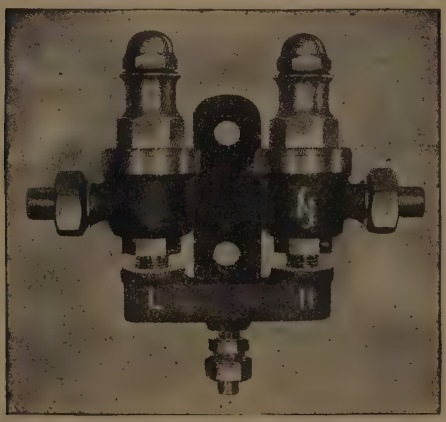


Fig. 280. Duplex Regulating Portion of Pressure Controller.

troller is in principle the same as that of a Duplex Pump Governor with the exception of the regulating tops, which connect to the brake pipe. In no position of the Brake Valve handle is there danger of the brake

pipe becoming over-charged, or equal to that in the main reservoir.

This equipment is designed so that two pressures may be carried in the brake pipe, and also in the main reservoir. It will be seen by reference to the piping diagram that there is a union three-way cock, from which pipes lead to the regulating tops, and supply which in this case is brake pipe pressure. The same arrange-

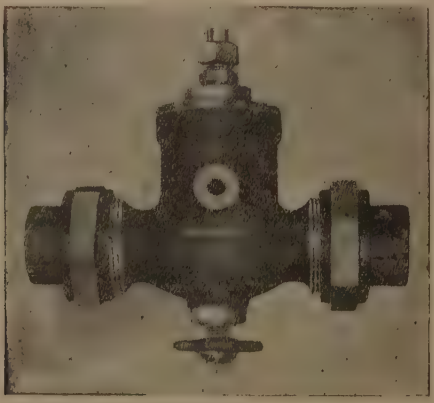


Fig. 281. Supply Portion of Pressure Controller.

ment also applies to the pump governor. A sectional view of this cock is shown in Figs 284 and 285. When one regulating top is cut in the other one is cut out and vice versa. This is done to relieve the strain on the regulating tops when not working. When the cocks are in the position shown in the piping diagram the low pressure regulating tops of the Controller and Duplex Pump

...vernor are cut in, giving a pressure of seventy pounds ... the brake pipe, and ninety pounds to the main reservoir. When the cocks are reversed, one hundred and ... pounds will then be carried in the brake pipe, and ... hundred and thirty pounds in the main reservoir.

... 280 is a phantographic view of the Duplex Pressure ... controller, and Fig. 281 is a view of the supply portion. Figs. 282 and 283 are sectional views of both the

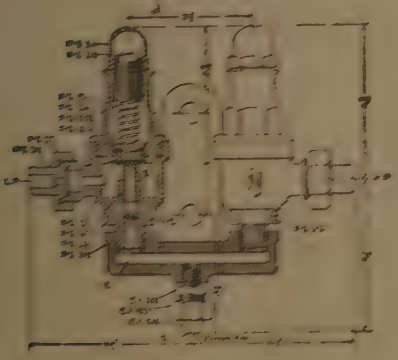


Fig. 281.

... and single regulating portion. Fig. 284 shows ... supply portion in section. Referring to Fig. 284, connection is made with the main reservoir at M. In the ... ends of the upper passage are 1 free to pass to the ... side of the valve P 1 pg. Connection M T leads to ... the regulating portion. Chamber M T and connection ... the regulating portion. Chamber M T and connection ... at 1, in Figs. 282 and 283.

... Diaphragm will rather a larger area than the

ing portion, as soon as the pressure in the brake pipe is great enough to overcome the resistance of the spring PG 10 which is holding the diaphragm PG 13 seated over port B, the pressure will pass through passage E to connection D, and by piping to the space E in the supply portion of the controller above the piston PG 4, forcing the piston, and valve PG 95 down until seated, cutting off communication between main reservoir and brake pipe.

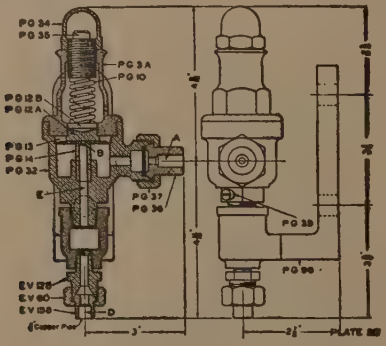


Fig. 283.

As soon as the pressure falls in the brake pipe below the adjustment of spring PG 10, the latter will force diaphragm PG 13 to its seat, closing off port B, whereupon pressure in passage E, and piping connecting supply and regulating portions, and space E above piston PG 4 will immediately escape to the atmosphere through the small port C in the regulating head of the controller, after which main reservoir pressure will lift valve PG 95 off its seat, and again open communication to the brake pipe.

Port X in the supply portion of the controller connects the under side of piston PG 4 with atmosphere, so that it will be free to operate and to discharge any leakage by the ring PG 24 or valve PG 95.

The regulating portions are provided with brackets so that they can be attached to the cab in some convenient place where they will be handy for adjustment. The adjustment of these regulating heads is accomplished by means of nut PG 35 which regulates the tension of spring PG 10.

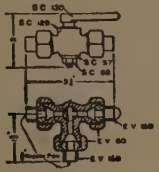


Fig. 284.

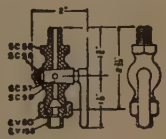


Fig. 285.

Each regulating head has a vent port C, and to avoid any unnecessary waste of air, one of these heads should be plugged with screw PG 33. The cut-out cock shown in Fig. 285 is used with the B2S equipment, between the regulating and supply portions. When this cock is closed the supply portion of the controller is cut off.

The hand wheel PG 45 can be used in descending grades if desired, to increase the brake pipe pressure to that of the main reservoir. By screwing the wheel up, it will lift the valve PG 95 off its seat and thus allow the two pressures to become equal. The Controller will then be inoperative, and main reservoir pressure will be free to pass to the brake pipe until the Controller is again restored to its operative condition.

The names of parts of the regulating portion are: PG 3A Spring Casing; PG 10 Regulating Spring; PG 12A and B Diaphragm button; PG 13 Diaphragm; PG 14 Air valve seat; PG 32 Diaphragm body; PG 33 Vent plug; PG 34 Cap; PG 35 Regulating nut; PG 36 Air union swivel (⅜" copper pipe); PG 37 Air union nut; PG 98 Duplex bracket; EV 60 Small union nut; EV 128 Small union stud; EV 158 small union swivel (⅜" copper pipe). The parts of the three-way cock are: SC 57 Washer; SC 58 Nut; SC 129 Body; SC 130 Plug; EV 60 Small union nut; EV 158 Union Swivel (⅜" copper pipe).

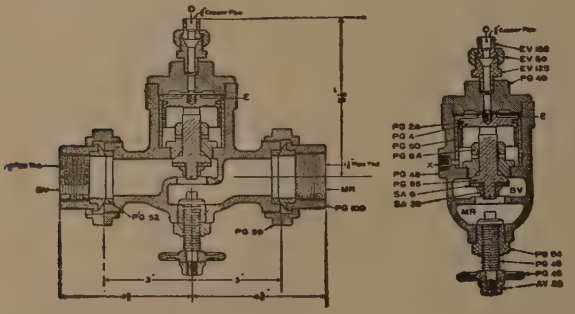


Fig. 286.

The parts of the supply portion are: PG 4 Piston; PG 6A Valve guide; PG 24 Piston ring; PG 45 Hand wheel; PG 46 Lifting Stem; PG 48 Body; PG 49 Cap; PG 94 Guide; PG 95 Valve; PG 99 1¼" union nut; PG 100 1¼" union swivel; EV 60 Small union nut; EV 128 Small union stud; EV 158 Union swivel (⅜" copper pipe); SA 6 Leather seat; SA 39 Valve stem nut; AV 28 Hand wheel nut.

ACCELERATOR VALVE.

This valve is designed to assist the Brake Valve in discharging brake pipe pressure when making service stops on long trains to bring about a more uniform application of the brakes, and to apply them more promptly than heretofore.

Fig. 287. Accelerator Valve.

The Valve is perfectly automatic in its operation, being governed entirely by the volume of air in the brake pipe, operating only when the train is of such a length

as to warrant the use of same. The operation is similar to that of the graduating mechanism in the Brake Valve, opening about four seconds after the Brake Valve handle has been moved to a graduating notch, and closing in about the same length of time after the graduating valve has closed.

Fig. 287 is an outside view of the Valve showing connection to brake pipe and exhaust which is through the street ell. A sectional view is shown in Fig. 288. The Valve is bolted to the end of the divided reservoir (Fig.

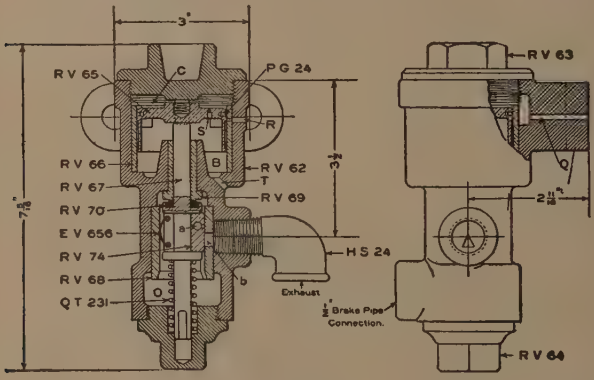


Fig. 288

279), and receives pressure from same through passage Q which connects to the space C above the piston RV 65. The brake pipe connection leads to the slide valve chamber O.

Chamber B is open to the atmosphere through port T, and in the operation of the Valve, will carry off the discharge of pressure through port S, and any leakage by the piston RV 65 or valve stem RV 67.

The slide valve RV 74, when at rest, laps the port b and exhaust, and is held in this position by the spring QT 231 through the medium of valve stem RV 67, which seats in the manner shown. Port b is triangular, the larger portion being at the bottom, and in operation brake pipe pressure is gradually cut off as the slide valve closes. Port a in the slide valve is oblong being just long enough to uncover the triangular port b, when the slide valve is wide open. To give the slide valve a slow closure port R is provided in the valve body, and port S through the piston RV 65 as shown. When the valve is in operation and brake pipe pressure is being discharged to the atmosphere through ports a and b, ports R and S are open to discharge the pressure above the piston and divided reservoir. As soon as the pressure in the divided reservoir has reduced sufficiently for the spring QT 231 to operate, it will move the valve slowly upward until the port R is cut off, which will then reduce the discharge from the reservoir about one-half, giving the slide valve the slow closure desired.

The valve operates when there are eight or more cars in a train, and requires from fifteen to seventeen pounds pressure in the divided reservoir to operate it. Any pressure passing into this reservoir, as with a shorter train than eight cars, will be discharged to the atmosphere through ports S and T, the slide valve remaining closed.

The proper names of parts of the accelerator valve are as follows: PG 24, Piston ring; RV 62, Body; RV 63, Upper cap; RV 64, Lower cap; RV 65, Piston; RV 67, Valve stem; RV 70, Leather seat; RV 74, Slide valve; QT 231, Spring; EV 656, Slide valve spring; HS 24, ½" Street ell.

STRAIGHT AIR REDUCING VALVE.

The purpose of this valve is to limit the pressure in the driver, and truck brake cylinders, to 40 pounds when using the straight air brake.

Fig. 289. Straight Air Reducing Valve.

Fig. 289 is a photographic view of the reducing valve and Fig. 290 a section showing the valves, passages, etc.

Connection from the brake valve is made to the union fitting A and by means of the passage C pressure is free to pass to the feed valve SA 26. Connection B leads to

double check valve and brake cylinders. During the time the tension of the spring against the diaphragm is stronger than the force exerted against it by the brake cylinder pressure, valve SA 26 will be held open, whereupon pressure from the main reservoir will be free to pass to the brake cylinders. As soon as the pressure

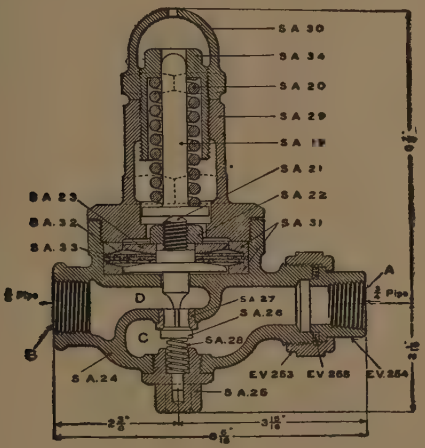


Fig. 290.

against the diaphragm is strong enough to overcome the resistance of the spring, the diaphragm will be moved upward, allowing the feed valve SA 26 to be closed by the spring SA 28, shutting off communication from the supply to the brake cylinders.

The names of the parts of this valve are as follows: SA 19, Regulating stem; SA 20, Regulating spring; SA

21, Diaphragm stem; SA 22, Nut; SA 23, Diaphragm Washer; SA 24, Body; SA 25, Feed valve cap nut; SA 26, Feed Valve; SA 28, Feed valve spring; SA 29, Spring box; SA 30, Check nut; SA 31, Diaphragm ring; SA 32, Diaphragm; SA 33, Diaphragm Shield; SA 34, Regulating nut; EV 253, ¾″ Union nut; EV 254, ¾″ Union swivel; EV 255, ¾″ Union gasket.

HIGH SPEED CONTROLLER WITH LEVER SAFETY VALVE.

This valve is operative when the locomotive equipment is set for high speed service.

Fig. 291. High Speed Controller.

Fig. 291 is an outside view showing the general arrangement. Fig. 292 is a section showing the operative parts.

The Safety Valve is for use at all times to graduate off brake cylinder pressure after an application of the

train brakes when same is desired and to regulate the pressure in the brake cylinders during high speed operations. It is set at 53 pounds, and should so be adjusted in service.

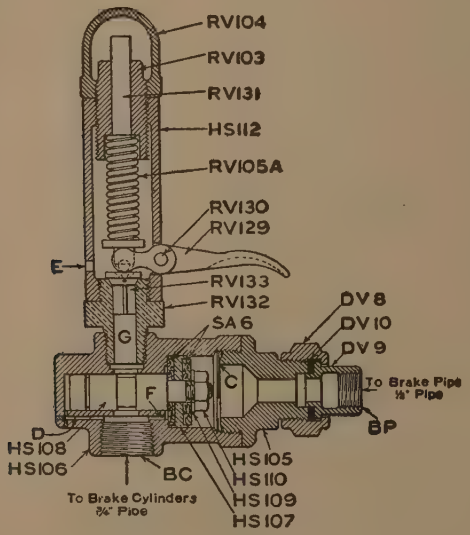


Fig. 292.

The High Speed Valve to which the Safety Valve is fastened connects with the brake cylinder pipe at BC and with brake pipe at BP.

The valve HS 108 with piston HS 107 operates when the brake pipe pressure is less than the pressure in brake cylinders. During all ordinary service applications the valve HS 108 will remain in position shown. In an emergency application when brake pipe pressure is

greatly reduced, the brake cylinder pressure will move the piston HS 107, and valve its full traverse to the seat C. This movement will restrict passage G leading to the safety valve, and atmosphere by the circular groove in the valve HS 108 being moved forward, closing a portion of the passage. This will give a gradual blow down from the brake cylinders through passage G until shut off by the Safety Valve. The valve will remain in this position until the brakes are released.

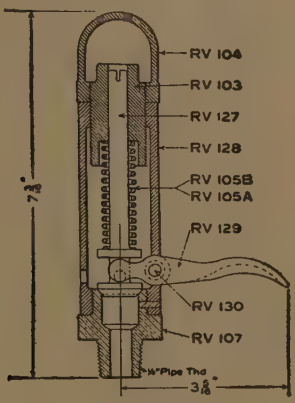


Fig. 293.

Ports F and D allow the brake cylinder pressure around the piston HS 107, and back of the valve HS 108, so that the piston is free to operate at a slight difference of pressure.

Fig. 293 is a sectional view of the lever safety valve, furnished with schedules B2, B2-S and B2-HP.

Fig. 294 shows the quick release valve which is used

with the B2-S equipment, for switch engine service, to quickly release the pressure from the driver brake cylinders.

The lever safety valves shown in Figs. 292 and 293 are for use at all times to graduate off brake cylinder pressure, after an application of train brakes, when the same is desired. These valves are set at fifty-three pounds, and should be so adjusted in service.

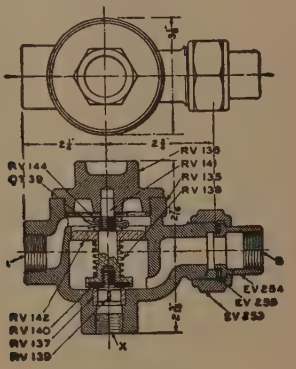


Fig. 294.

The two lever safety valves, although similar in appearance, are different in operation. In Fig. 292 the valve RV 133 is of a pop-safety valve design, and when forced open will remain so until the pressure beneath it has fallen to a trifle less than the force exerted against it by the spring RV 105 A. The safety valve shown in Fig. 293 is an ordinary blow-down pop valve, and while it will operate and reduce brake cylinder pressure to the desired amount, is not as free an operating valve as

the one shown in Fig. 292. It is obvious to state that these lever safety valves are also for use to keep the brake cylinder pressure within a certain prescribed limit, as, if they were not used, an application of the straight air brake, followed by one of the automatic, would greatly increase the brake cylinder pressure over the prescribed limit.

The quick release valve shown in Fig. 294, as before stated, is for use with schedule B2-S switch engine equipment. This valve is to hasten the release after an application of the automatic or straight air brakes. Referring to Fig. 294, connection A leads to the double check valve as shown in the piping diagram of this equipment. Connection B leads to the driver brake cylinders and connection X to the exhaust.

QUESTIONS.

904. What is the latest addition to the New York Duplex Air Brake System?

905. How many of these, and what are they?

906. Name the different systems covered by these three equipments?

907. In what leading features do the B2 equipments differ from older New York systems previously described?

908. What other advantage is gained by its use?

909. What advantage is gained by the use of the accelerator valve?

910. What other advantage is there in connection with its use?

911. For what conditions of service is the plain B2 designed.

912. For what class of service is the B2S equipment adapted?

913. For what class of service is the B2HP equipment designed only?

914. How many pressures may be carried in the brake pipe, or in the main reservoir, with the B2H.P.?

915. How are these pressures regulated?

916. How are the regulating portions operated?

917. For what kind of service is the B2H.S. equipment adapted?

918. How are the pressures regulated with this latter equipment?

919. How are the automatic brakes applied to locomotive and train?

920. How are they released?

921. How are the train brakes released, and the locomotive brakes held?

922. How are both released?

923. How are the locomotive brakes released?

924. How are the locomotive brakes (straight air) applied?

925. How are the brakes applied in an emergency?

926. In case a hose bursts, the train parts, or a conductor's valve opens thereby applying the brakes, what should be done?

927. After an application of the train brakes, how may the locomotive brakes be graduated off, or entirely released if desired?

928. How may the pressure in the locomotive brake cylinders be observed at all times?

929. When two, or more locomotives are in a train, what should be done with the air brake equipment on those locomotives from which the brakes are not operated?

930. In case it becomes necessary to cut out the straight air brake, what must be done?

931. How may the automatic brake be cut out?

932. How may the cut out cock be located so that the auxiliary reservoirs will remain charged while the brake is cut out?

933. What advantage would this be in descending long grades?

934. What are the functions of cut out cocks Nos. 3 and 6?

935. What is the function of main reservoir cut out cock No. 4?

936. What is the straight air controller designed for?

937. When should cut out cocks Nos. 5-6 and 7 be used?

938. Mention some of the principal points of difference between the B2 brake valve, and the B, and B1 valves?

939. What is the purpose of full automatic release, and straight air application position?

940. What functions are performed by the valve, in running, and straight air release position?

941. When should Lap position be used?

942. What are the functions of the graduating positions?

943. When is emergency position to be used?

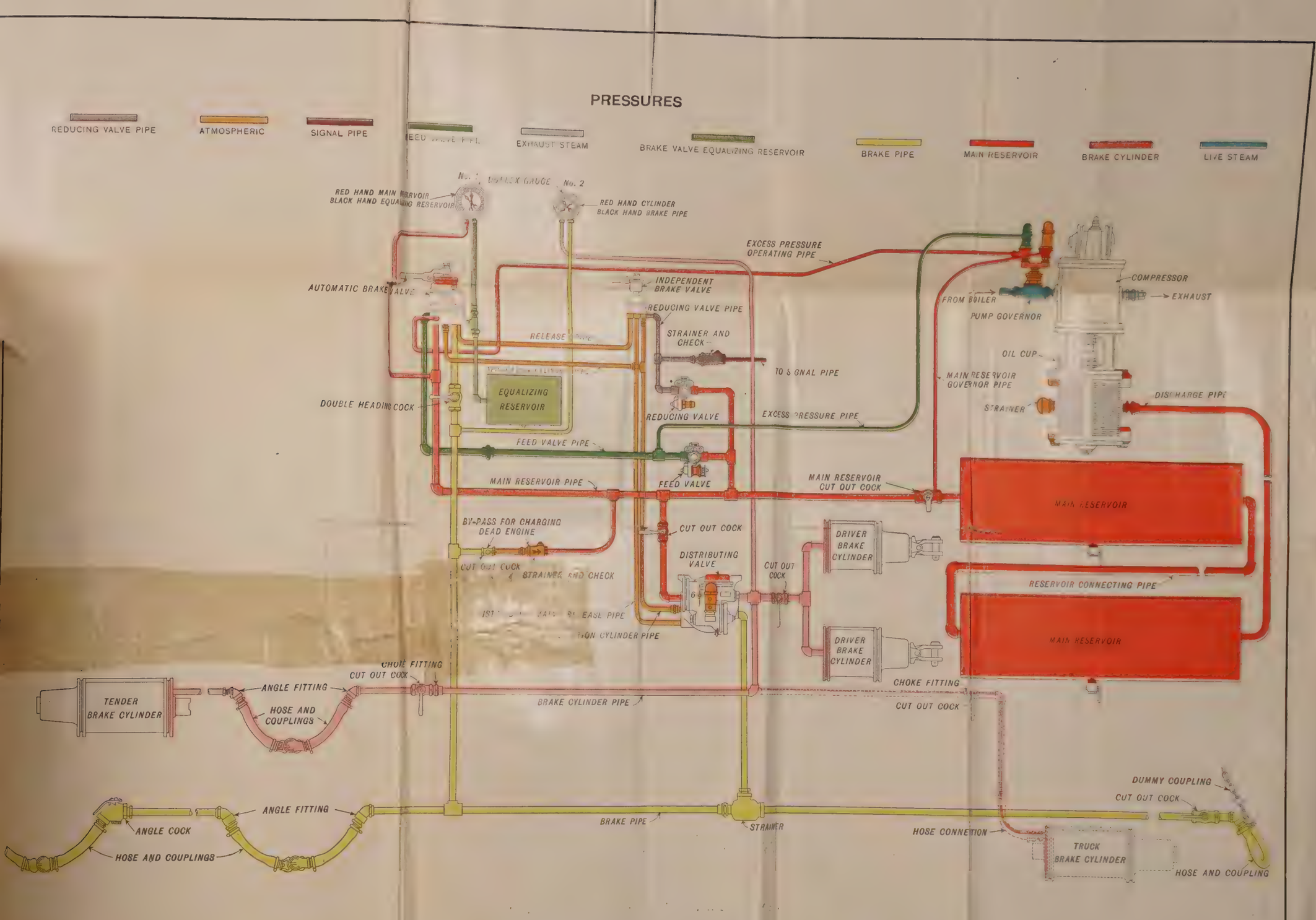
944. What are some of the advantages gained by using the duplex pressure controller, and double pressure system?

945. What is the Accelerator valve designed to accomplish?

946. Is it automatic in operation?

947. What is the purpose of the straight air reducing valve?

948. When is the high speed controller, with lever safety valve operative?



WESTINGHOUSE AIR BRAKE SERIES

INSTRUCTION DIAGRAM OF PIPING CONNECTIONS, No. 6 E T LOCOMOTIVE BRAKE EQUIPMENT

ET LOCOMOTIVE BRAKE EQUIPMENT.

The new locomotive equipment illustrated and described in this article is designated by the symbol ET. It differs materially from the present combined automatic and straight air brake in that it consists of considerably less apparatus. In operation it possesses all the advantages of the latter type of brake equipment and several other important ones which are necessary in modern locomotive brake service to produce satisfactory results.

The design of the principal valves comprising the ET equipment is such that it may be applied to any locomotive regardless of the service in which it is employed without change or modification in any of its parts; and the locomotive so equipped may be used in any kind of service, such as high speed passenger, double-pressure control, all ordinary passenger and freight, and in all kinds of switching service, without change or special adjustment of the brake apparatus. All principal valves are so designed that they may be removed for repairs and replacement without disturbing the pipe joints.

In operation its important advantages are: The locomotive brakes may be controlled with or independently of the train brakes and this without regard to the position of the locomotive in the train, whether coupled to another, as in double heading, or used as a helper and assigned to any position in the train.

They may be applied with any desired pressure between the minimum and the maximum attainable, and

this pressure will be automatically maintained in the locomotive brake cylinders regardless of leakage and variation in piston travel, undesirable though these defects are, until released by the brake valve.

They can be perfectly graduated on or off either in the automatic or in the independent application; hence, in all kinds of service the train may be handled without shock or danger of parting, and in passenger service especially smooth, accurate stops can be made with greater ease than was heretofore possible.

MANIPULATION.

The instructions for manipulating the ET equipment are practically the same as those given for the combined automatic and straight air brake; therefore, no radical departure from present methods of brake manipulation is required to get the desired results.

The necessary instructions are briefly as follows:

When not in use, carry the handles of both brake valves in running position.

To apply the locomotive and train brakes, move the handle of the automatic brake valve to the service position, making the required brake-pipe reduction, then back to lap position, which is the one for holding brakes applied.

To release the train brakes, move the handle to the release position and hold it there until all train brakes are released; then, move it to holding position, graduating off the locomotive brakes by short, successive movements between running and holding positions, aiming to have the locomotive brakes entirely released as the train stops.

To apply the brakes in an emergency, move the handle of the automatic brake valve quickly to emergency position and leave it there until the train stops, or the danger is passed.

To make a smooth and accurate two-application passenger stop, make the first application sufficiently heavy to bring the speed of the train down to about 15 miles per hour at a convenient distance from the stopping point, then release train brakes by moving the handle to release position, then the locomotive brakes by moving it to running position for two or three seconds before re-applying. A little experience with the ET equipment will enable the engineer to make smooth and accurate stops with much greater ease than was heretofore possible.

When using the independent brake only, the handle of the automatic brake valve should be carried in running position. The independent application may be released by moving the independent-brake-valve handle to running position. Release position is for use when the automatic brake valve handle is not in running position.

While handling long trains of cars, in road or switching service, the independent brake should be operated with care and judgment, to prevent damage to the cars and lading, caused by running the slack in or out too hard. In cases of emergency arising while the independent brake is applied, apply the automatic brake instantly. The safety valve will restrict the brake cylinder pressure to the proper maximum. The brakes on the locomotive and on the train should be alternated in heavy grade service, to prevent overheating of driving-wheel tires and to assist the pressure retaining valves in holding the train while the auxiliary reservoirs are being recharged.

After all brakes are applied automatically, to gradu-

ate off or entirely release the locomotive brakes only, use release position of the independent brake valve.

The cylinder gauge will show at all times the pressure in the locomotive brake cylinders, and this gauge should be observed in all brake manipulation.

Release Position of the *Independent Brake Valve* will release the locomotive brakes under any and all conditions.

The train brakes should invariably be released before detaching the locomotive, holding with hand brakes where necessary. This is especially important on a grade as there is otherwise no assurance that the car, cars, or train so detached will not start when the air brakes leak off, as they may in a short time where there is considerable leakage.

The automatic brakes should never be used to hold a standing locomotive, or a train even where the locomotive is not detached, for longer than ten minutes, and not for such time if the grade is very steep or the condition of the brakes is not good. The safest method is to hold with hand brakes only, and keep the auxiliary reservoirs fully charged so as to guard against a start from brakes leaking off, and to be ready to obtain any part of full braking power immediately on starting.

The independent brake is a very important safety feature in this connection, as it will hold a locomotive with a leaky throttle, or quite a heavy train on a fairly steep grade if, as the automatic brakes are released, the slack is prevented from running in or out, depending on the tendency of the grade, and giving the locomotive a start. Illustrating the best method by a descending train, apply the independent brake heavily as the stop is being completed, thus bunching the train solidly; then, when stopped, place and *leave* the handle of the independent

brake valve in application position, release the automatic brakes and keep them charged. Should the train start through inability of the independent brakes to hold it, the automatic brakes will have been sufficiently recharged to make an immediate stop, and in which case enough hand brakes should be applied to render the necessary aid to the independent brakes.

Many runaways and some serious wrecks have resulted through failure to comply with the foregoing instructions.

When leaving the engine while doing work about it, or when it is standing at a coal chute or water plug, always leave the independent brake valve handle in application position.

In case the automatic brakes are applied by a bursted hose, a break-in-two or the use of a conductor's valve, place the handle of automatic brake valve in lap position.

Where there are two or more locomotives in a train, the double cut-out cock in the brake pipe under the automatic brake valve should be turned to close the brake pipe, and the automatic-brake-valve handle should be placed on lap on each except the one from which the brakes are being handled.

Before leaving the roundhouse, the engineer should try the brakes with both brake valves, and see that no serious leaks exist. The pipes between the distributing valve and the brake valves should be absolutely tight.

PARTS OF THE EQUIPMENT.

1. The Air Pump to compress the air.
2. The Main Reservoirs, in which to store the air and collect water and dirt.

3. A DUPLEX PUMP GOVERNOR to control the pump when the pressures are attained for which it is regulated.

4. A DISTRIBUTING VALVE, and small double-chamber reservoir to which it is attached, placed on the locomotive to perform the functions of triple valves, auxiliary reservoirs, double check valve, high-speed reducing valves, etc.

5. TWO BRAKE VALVES, the AUTOMATIC to operate locomotive and train brakes, and the INDEPENDENT to operate locomotive brakes only.

6. A FEED VALVE to regulate the brake-pipe pressure.

7. A REDUCING VALVE to reduce the pressure for the independent brake valve, and for the air signal system when used.

8. TWO AIR GAUGES; one, a DUPLEX to indicate brake-pipe and main-reservoir pressures; the other, a SINGLE POINTER to indicate locomotive brake-cylinder pressure.

9. DRIVER, TENDER, and TRUCK-BRAKE CYLINDERS, CUT-OUT COCKS, AIR STRAINERS, HOSE COUPLINGS, FITTINGS, etc., incidental to the piping, for purposes readily understood.

The piping hereafter referred to is named as follows:

RESERVOIR PIPE: Connects the main reservoir to the Automatic Brake Valve, Distributing Valve, Feed Valve, and Reducing Valve.

FEED-VALVE PIPE: Connects the Feed Valve to the Automatic Brake Valve.

REDUCING-VALVE PIPE: Connects the Reducing Valve to the Independent Brake Valve, and to the Signal System, when used.

BRAKE PIPE: Connects the Automatic Brake Valve

with the Distributing Valve and all Triple Valves on the cars in the train.

Brake-Cylinder Pipe: Connects the Distributing Valve with the Driver, Tender and Truck-Brake Cylinders.

Application-Chamber Pipe: Connects the Application Chamber of the Distributing Valve to the Automatic Brake Valve through the Independent Brake Valve.

Double-Heading Pipe: Connects the Application Chamber exhaust port of the Distributing Valve to the Automatic Brake Valve through the Double Cut-Out Cock.

ARRANGEMENT OF APPARATUS.

A piping diagram of the ET equipment is shown in Fig. 295.

Air compressed by the pump passes as usual to the main reservoirs and the reservoir pipe. The main-reservoir cut-out cock is to cut off the supply of air when removing any of the apparatus except the governor. The end toward the main reservoir is tapped for a connection to the maximum pressure head of the Pump Governor. When closed it discharges the air from the pipe between it and the automatic brake valve.

Beyond the main-reservoir cut-out cock, the reservoir pipe has four branches, one of which runs to the automatic brake valve, one to the feed valve, one to the reducing valve, and one to the distributing valve. As a result, the automatic brake valve receives air from the main reservoir in two ways, one direct and the other through the Feed Valve.

The Feed-Valve Pipe from the feed valve to the auto-

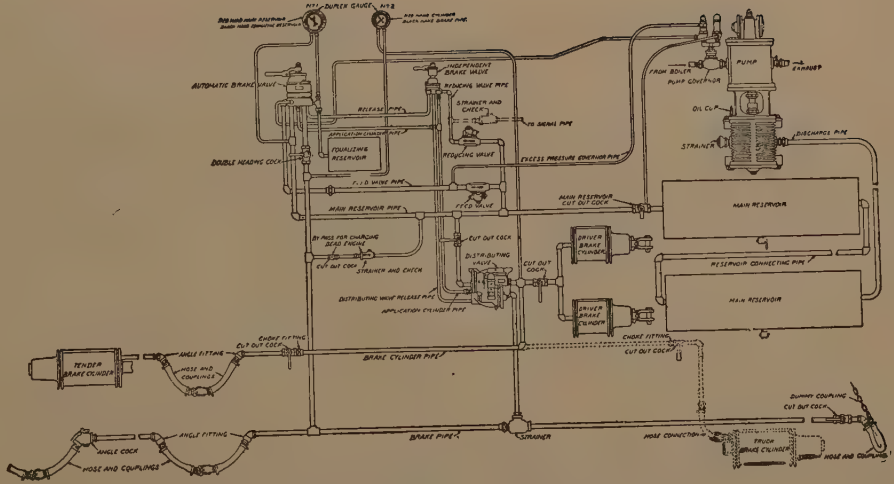


FIG. 295. PIPING DIAGRAM OF THE ET EQUIPMENT

matic brake valve has a branch to the top of the excess-pressure head of the duplex pump governor.

The third branch of the reservoir pipe connects with the reducing valve. Air at the pressure for which this valve is set (45 pounds) is thus supplied to the independent brake valve through the reducing-valve pipe. When the signal system is installed, it is connected to the reducing valve pipe, in which case the reducing valve takes the place of the signal reducing valve usually employed to supply the train air-signal system. In the branch pipe supplying the signal are placed a combined strainer and check-valve, and a special choke fitting. The former prevents any dirt from reaching the check valve and choke plug. The check valve prevents air from flowing back from the signal pipe when the independent brake is applied. The choke plug prevents the reducing valve from raising the signal-pipe pressure so quickly as to destroy the operation of the signal.

The distributing valve has five pipe connections, made through the double-chamber reservoir, three on the left and two on the right. Of the three on the left, the upper is the supply from the main reservoir; the intermediate is the double-heading pipe, leading through the double cut-out cock, when turned to cut out the brake valve from the brake pipe, to the automatic brake valve; and the lower is the application-chamber pipe, leading through the independent-brake valve, when the handle is in running position, to the automatic brake valve. Of the two on the right, the lower is the brake-pipe-branch connection, and the upper is the brake-cylinder pipe branching to all brake cylinders on the engine and tender. In this pipe are placed cocks for cutting out the brake cylinders when necessary, and in the engine truck and

tender brake cylinder cut-out cocks are placed special choke fittings to prevent serious loss of main-reservoir air, and the release of the other locomotive brakes during a stop, in case of burst brake cylinder hose connection. The cylinder gauge is connected with the brake cylinder pipe.

The automatic-brake-valve pipe connections, other than already mentioned, are the brake-pipe branch through the double cut-out cock, the main-reservoir, the equalizing reservoir, the duplex gauge, and the lower connection to the excess-pressure head of the pump governor.

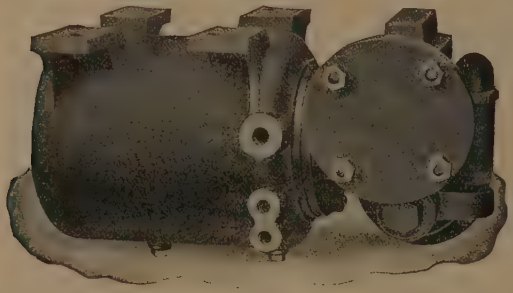


FIG. 296. DISTRIBUTING VALVE AND DOUBLE-CHAMBER RESERVOIR

CONNECTIONS:

SUP—Main-Reservoir Pipe; ABV—Double-Heading Pipe; SBV—Application-Chamber Pipe

THE DISTRIBUTING VALVE.

This valve is the important feature of the ET equipment. Fig. 296 is a photographic view of the left side of the valve and its double-chamber reservoir. The three pipe connections, as previously referred to, are plainly

shown. Fig. 297 is a similar view of the right side, showing the pipe connections there and the two chambers of

FIG. 297. DISTRIBUTING VALVE AND DOUBLE-CHAMBER RESERVOIR

PIPE CONNECTIONS:
Upper—Brake-Cylinder Pipe; Lower—Brake Pipe

the reservoir; also the safety valve 34, which is an essential part of the distributing valve. To simplify the tracing of the ports and connections, the various positions of this

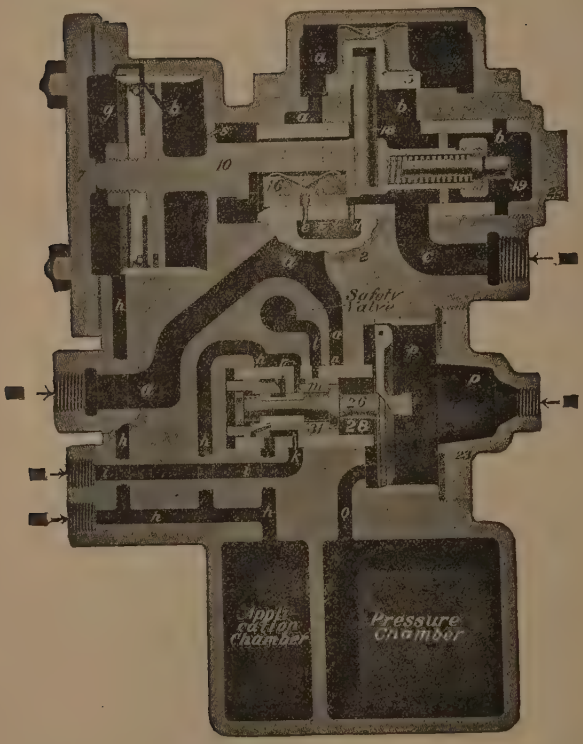


FIG. 298. THE DISTRIBUTING VALVE, DIAGRAMMATIC CONNECTIONS:

MR—Main-Reservoir Pipe; DH—Double-Heading Pipe; AC—Application-Chamber Pipe; BC—Brake Cylinder Pipe; BP—Brake Pipe.

valve are illustrated in ten diagrammatic drawings; that is, the valve is distorted to show the parts differently than actually constructed, with the object of explaining the operation clearly instead of showing exactly how they are designed. The chambers of the reservoir are for convenience indicated at the bottom as a portion of the valve itself. In Fig. 308, equalizing piston 26, graduating valve 28, and equalizing slide valve 31, are shown as actually constructed. But as there are ports in the valves which cannot thus be clearly indicated, the diagrammatic illustrations show each slide valve in two parts, one below and the other above the piston stem, with similar division of parts in the bush.

Fig. 298 shows the operative parts in the same position as in Fig. 299 and is used merely for the sake of greater clearness. Referring to these figures it will be seen that main-reservoir pressure is always present in the chamber surrounding application valve 5 by its connection through passage *a, a,* to the main-reservoir pipe. Chambers *b* to the right of application piston 10 are always in free communication with the brake cylinder through passage *c* and brake-cylinder pipe. Chamber *g* at the left of application piston 10 is a portion of the application chamber, being always connected with it by passage *h,* and is also connected to the brake valves through the application-chamber pipe.

Independent Application. When the handle of the Independent Brake Valve is moved to the application position, air from the main reservoir, limited by the reducing valve to a maximum of 45 pounds, is allowed to flow to the application chamber, forcing application piston 10 to the right as shown in Fig. 300. We will assume that 45 pounds is so admitted and maintained. This

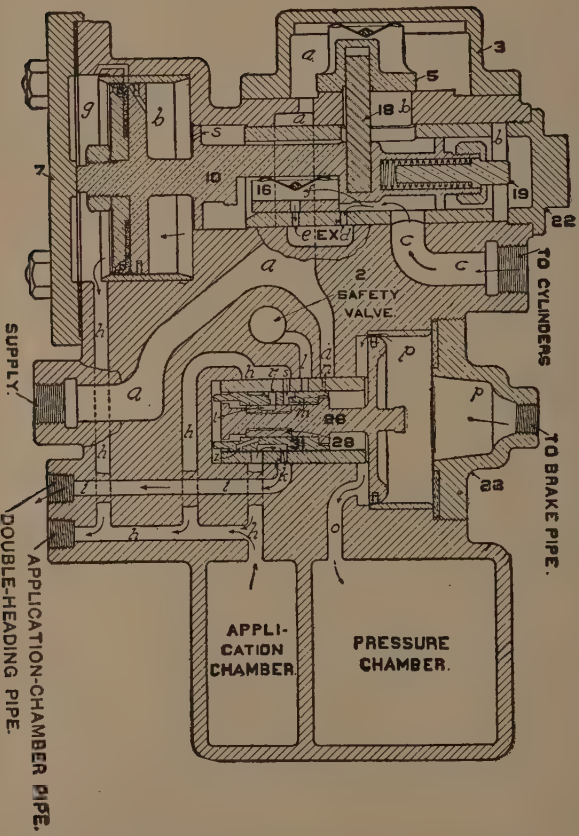


FIG. 299. RELEASE, AUTOMATIC OR INDEPENDENT

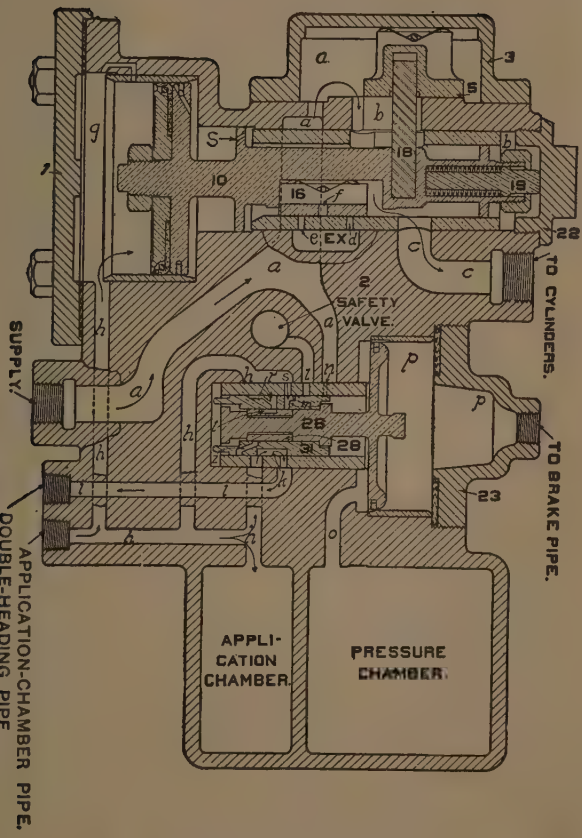


FIG. 300. INDEPENDENT APPLICATION

movement of application piston 10 causes exhaust valve 16 to close exhaust ports *e* and *d*, and the graduating stem 19 to compress its spring; also open application valve 5 by its connection with the piston stem by pin 18. Main reservoir air then flows through port *b* and passage *c* to the brake cylinders until their pressure and that in chamber *b* equals the application-chamber pressure, in this case 45 pounds. The graduating spring then forces the application piston 10 to the left until application valve 5 closes port *b*, but without moving exhaust valve 16. This position shown in Fig. 301 is known as INDEPENDENT LAP.

From the above description it will be seen that application piston 10 has application chamber pressure on one side and brake-cylinder pressure on the other. When either pressure varies, the piston will move toward the lower. Consequently if that in chamber *b* is reduced, by brake-cylinder leakage, the pressure maintained in the application chamber will force piston 10 to the right, opening application valve 5 and again admitting main reservoir air to the brake cylinders until the pressures on both sides of piston 10 are again equal, when the graduating spring will force the piston back to lap position. In this way the brake-cylinder pressure is always maintained to that in the application chamber. This is called the pressure maintaining feature.

INDEPENDENT RELEASE. When the handle of the independent brake is moved to release position, a direct opening is made through the rotary valve from the application chamber to the atmosphere. This permits the pressure in the application chamber to escape; therefore, as this pressure is being exhausted, brake-cylinder pressure in chamber *b* moves application piston 10 to the left,

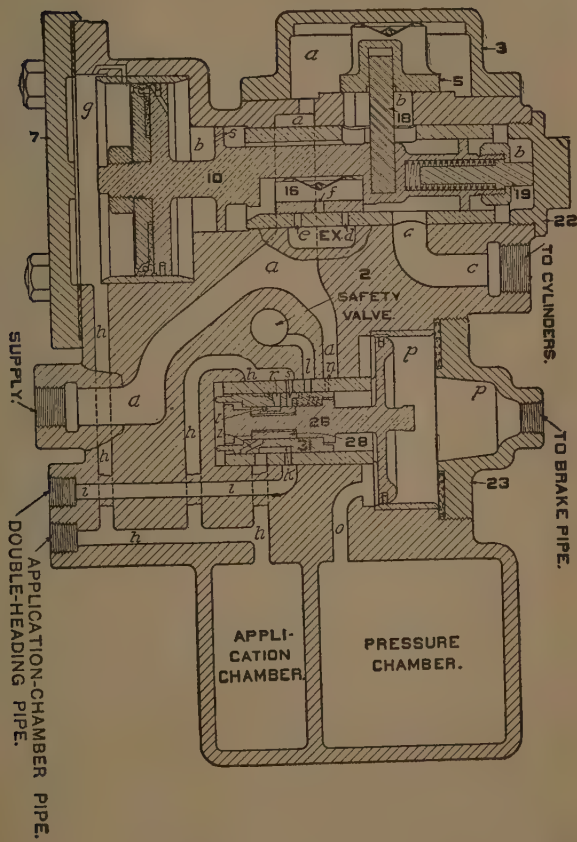


FIG. 301. INDEPENDENT LAP

causing exhaust valve 16 to open exhaust ports *e* and *d* as shown in Fig. 299, thereby allowing brake-cylinder pressure to escape to the atmosphere.

If the independent brake valve is returned to lap before all of the application-chamber pressure has escaped, the application piston 10 will return to independent lap position as soon as the brake-cylinder pressure is reduced a little below that remaining in the application chamber.

AUTOMATIC OPERATION.

During automatic operation of the brakes, the lower movable parts, known as the equalizing parts, are brought into action.

Automatic Release. Referring to Fig. 299, which shows the movable parts of the valve in the release position, it will be seen that as chamber *p* is connected to the brake pipe, brake-pipe air flows through the feed groove around the top of piston 26 into the chamber above the slide valve 31, and through port *o* to the *pressure chamber,* until the pressures on both sides of the piston are equal.

Service. When a service application is made with the automatic brake valve, the brake-pipe pressure in chamber *p* is reduced, causing a difference in pressure on the two sides of this piston, which results in the piston moving toward the right. The first movement of the piston closes the feed groove, and at the same time moves the graduating valve until it uncovers the upper end of port *z* in the equalizing slide valve 31. As the piston continues its movement, the shoulder on the end of its stem engages the slide valve, which is then also moved to the right until port *z* in the slide valve registers with port

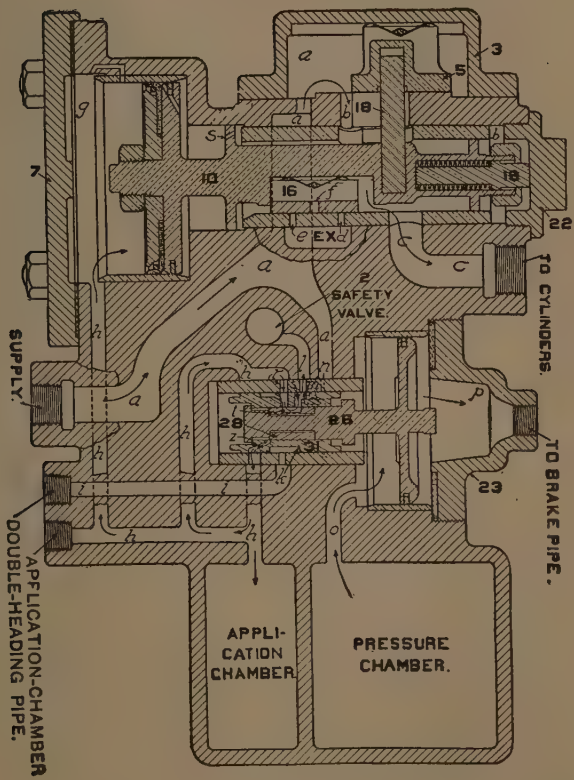


FIG. 302. AUTOMATIC SERVICE

h in the seat. As the slide valve chamber is always in communication with the pressure chamber, air can now flow from it to the application chamber. This pressure forces application piston 10 to the right, as shown in Fig. 302, causing application valve 5 to uncover port *b* and allow main reservoir air to flow to the brake cylinders through port *c*, as in an independent application.

During the movement just described, cavity *t* in the graduating valve connects ports *r* and *s* in the equalizing slide valve, and by the same movement ports *r* and *s* are brought into register with ports *h* and *l* in the seat, thus establishing a communication from the application chamber to the safety-valve, which being set at 53 pounds, limits the brake-cylinder pressure to this amount during a full service application.

The amount of pressure resulting in the application chamber for a certain brake-pipe reduction, depends on the comparative volumes of the application and pressure chambers. These volumes are such that with 70 pounds in the pressure chamber and nothing in the application chamber, if they are allowed to remain connected by the ports in the slide valve, they will equalize at about 50 pounds.

Service Lap. The conditions just described continue until the pressure in the *pressure chamber* is reduced enough below that in the brake pipe to cause the difference in pressure on the two sides of piston 26 to force it and graduating valve 28 to the left until the shoulder on the piston stem strikes the right-hand end of slide valve 31, the position indicated in Fig. 303, and known as Service Lap. In this position, graduating valve 28 has closed port *z* so that no more air can flow from the *pressure chamber* to the application chamber;

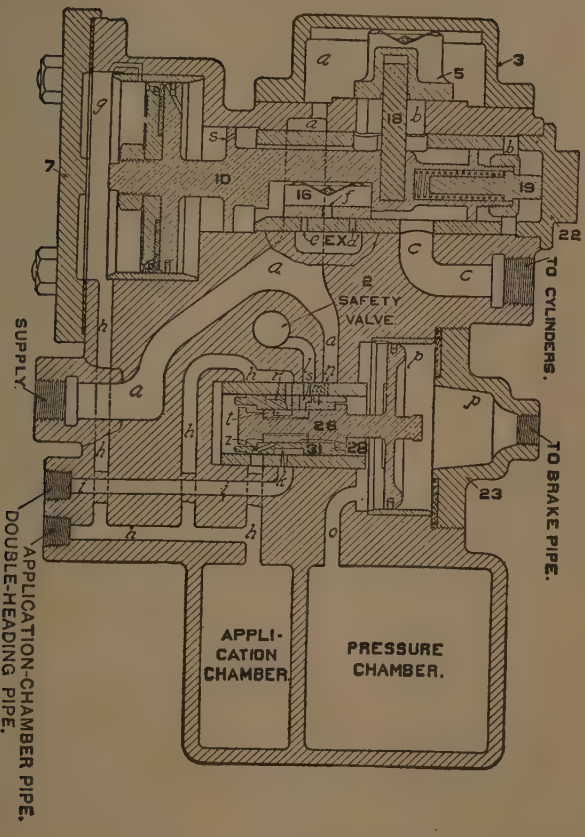


FIG. 303. SERVICE LAP

and it also has closed port *s*, cutting off communication to the safety valve. The flow of air past application valve 5 to the brake cylinders continues until their pressure equals that in the application chamber when the graduating spring forces piston 10 to the position shown in Fig. 303, closing port *b*. The brake-cylinder pressure is then practically the same as that in the *application chamber.*

It will be seen that whatever pressure exists in the *application chamber* will be maintained in the brake cylinder by the "pressure maintaining" feature already described.

When the automatic brake valve is placed in release position, and the brake-pipe pressure in chamber *p* is increased above that in the pressure chamber, equalizing piston 26 moves to the left, carrying with it equalizing slide valve 31 and graduating valve 28 to the release position as shown in Fig. 299. The feed groove now being open permits the pressure in the pressure chamber to equalize with that in the brake pipe as before described. This action does not release the locomotive brakes because it does not discharge application chamber pressure. The double-heading pipe is closed at the double cut-out cock, and the application chamber pipe is closed by the rotary valve of the automatic brake valve. Therefore, to release the locomotive brakes, the automatic brake valve must be moved to running position, or the independent brake valve must be held in release position, in which positions the rotary valve of either will connect the application chamber pipe with the atmosphere. As the application chamber pressure escapes, the cylinder pressure will force application piston 10 to the left until

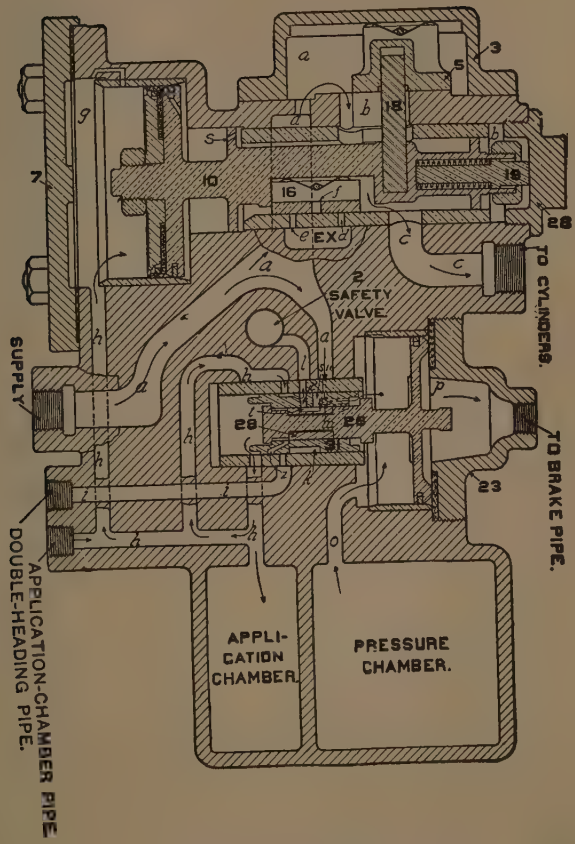


FIG. 304. EMERGENCY

exhaust valve 16 uncovers exhaust ports *d* and *e*, allowing brake-cylinder pressure to escape.

Emergency. When a sudden and heavy brake-pipe reduction is made, as in an emergency application, the pressure in the pressure chamber forces application piston 26 to the right until it strikes against the leather gasket beneath head 23 as shown in Fig. 304. This movement causes slide valve 31 to uncover port *h* in the bush, making a large opening from the *pressure chamber* to the *application chamber*, so that they quickly become equalized. In the emergency position of the automatic brake valve, the volume of the equalizing reservoir is connected to that of the application chamber. This reservoir volume, together with that of the pressure chamber at 70 pounds pressure, equalizes into the application chamber at about 60 pounds. The dotted port *m* in the slide valve registers with port *n* in the seat connecting with supply passage *a*, allowing air from the main reservoir to enter the slide valve and application chambers. A cavity in the slide valve registers with port *h* in the seat. Port *r* in the slide valve registers with port *l* leading to the safety valve. The cavity and port *r* in the slide valve are connected by a small port, the size of which permits the air in the application chambers to escape a little faster than ports *m* and *n* can supply it, preventing the pressure from rising above the amount desired.

In High-Speed Brake Service, the feed valve is regulated for 110 pounds brake-pipe pressure instead of 70, and main-reservoir pressure is 130 or 140 pounds. Under these conditions an emergency application raises the *application chamber* pressure to about 85 pounds, but the area of the small passage to port *r* is so proportioned that the flow of *application-chamber* pressure to the safety

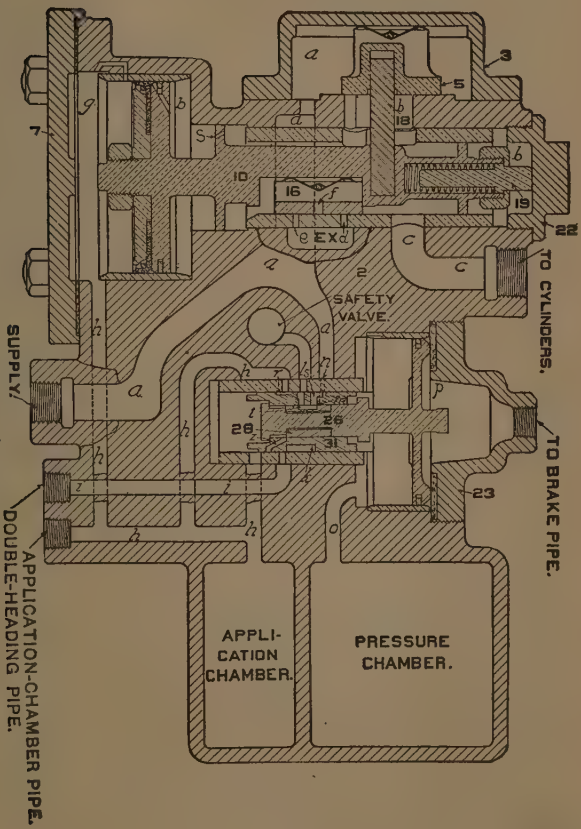


FIG. 305. EMERGENCY LAP

valve is just enough greater than the supply through *m*, to decrease that pressure in practically the same time and manner as is done by the high-speed reducing valve, until it is approximately 60 pounds. The application portion operates similarly to, but more quickly than, in the service application.

Emergency Lap. The above conditions continue until the brake cylinder pressure equals the *application-chamber* pressure, when parts of the valve assume the position known as the *Emergency Lap* and shown in Fig. 305.

The release after an emergency is the same as that following service applications.

Fig. 306 shows the position the distributing valve parts will assume, if the application-chamber pressure is discharged by the independent brake valve during an automatic application. This results in the upper movable portion going to the release position, and relieving brake-cylinder pressure, without changing the conditions in either the *pressure-chamber* or chamber *p;* consequently, the equalizing portion does not move, until released by the automatic brake valve.

Double Heading. It will be noted that in all of the above descriptions of the distributing valve, no reference has been made to the double-heading pipe connection. This is only used when the engine does not control the train brakes, and it then becomes an exhaust opening for the distributing valve when the automatic brake valve is on lap, and cut off from the brake pipe by the double cut-out cock. This will be better understood from the description of the pipe connections as already explained. The operation of the distributing valve is similar to that described during automatic brake applications with the

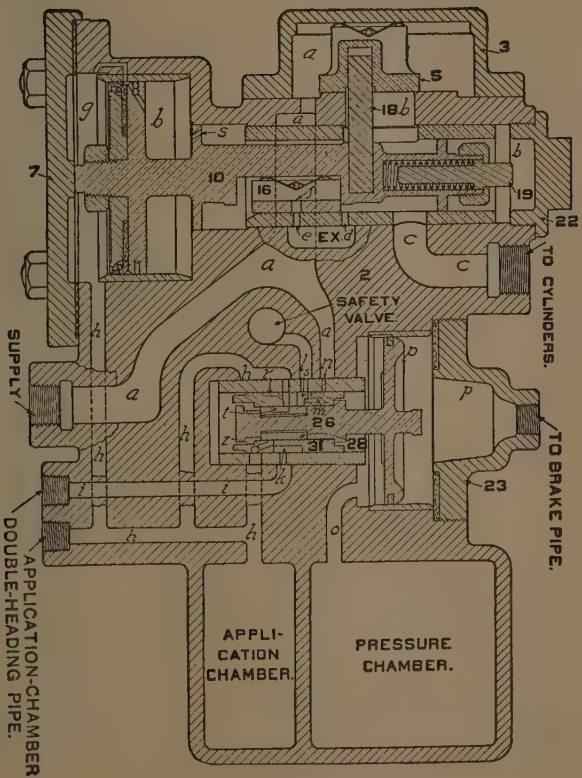
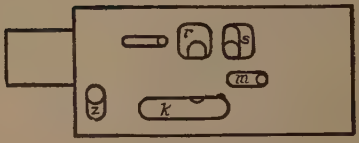


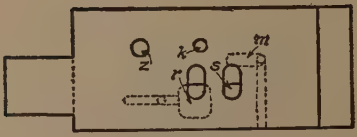
FIG. 306. RELEASE POSITION

When Locomotive Brake is released by Independent Brake Valve after an application by Brake Pipe Reduction

PLAN OF
GRADUATING VALVE.



FACE OF SLIDE VALVE.



PLAN OF SLIDE VALVE

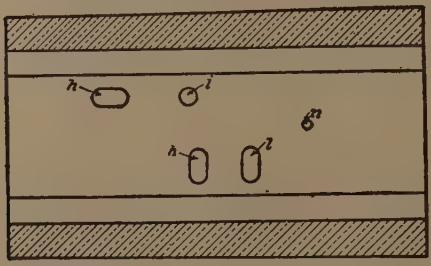


FIG. 307. GRADUATING VALVE, EQUALIZING SLIDE VALVE, AND SLIDE VALVE SEAT

exception of the release, which is brought about by the equalizing piston 26 moving to the release position and causing exhaust cavity in the equalizing slide valve 31

FIG. 308. DISTRIBUTING VALVE CONNECTIONS:
MR—Main Reservoir Pipe; DH—Double-Heading Pipe; AC—Application-Chamber Pipe; BC—Brake-Cylinder Pipe; BP—Brake Pipe

to connect ports *i* and *h* in the slide valve seat, thereby permitting the pressure in the application chamber to escape to the atmosphere through the double heading

pipe, the double cut-out cock, and the automatic brake valve. In double heading, therefore, the release of the distributing valve is similar to that of a triple valve.

To remove piston 10 and slide valve 16, it is absolutely necessary to *first* remove cover 3, slide valve 5 and valve pin 18.

Referring to Figs 298 and 308, the proper names of parts of this apparatus are as follows: 2, Body; 3, Application-Valve Cover; 4, Cover Screw; 5, Application Valve; 6, Application-Valve Spring; 7, Application-Cylinder Cover; 8, Cylinder-Cover Bolt and Nut; 9, Cylinder-Cover Gasket; 10, Application Piston; 11, Piston Follower; 12, Packing-Leather Expander; 13, Packing Leather; 14, Application-Piston Nut; 15, Application-Piston Packing Ring; 16, Exhaust Valve; 17, Exhaust-Valve Spring; 18, Application-Valve Pin; 19, Graduating Stem; 20, Graduating Spring; 21, Graduating-Stem Nut; 22, Upper Cap Nut; 23, Equalizing Cylinder Cap; 24, Cylinder Cap Bolt and Nut; 25, Cylinder-Cap Gasket; 26, Equalizing Piston; 27, Equalizing-Piston Packing Ring; 28, Graduating Valve; 29, Graduating-Valve Spring; 31, Equalizing Slide Valve; 32, Equalizing-Slide-Valve Spring; 33, Lower Cap Nut; 34, Safety Valve; 35, Double-Chamber Reservoir; 36, Reservoir Stud and Nut; 37, Reservoir Drain Plug; 38, Distributing-Valve Drain Plug; 39, Application-Valve-Cover Gasket; 40, Application Piston Cotter; 41, Distributing-Valve Gasket.

Fig. 309 is a sectional view of the safety valve which is a necessary part of the distributing valve. It is of an improved type, which insures reliability of operation. It is unlike the ordinary safety valve, as its construction is such as to cause it to close quickly with a "pop" action,

insuring its seating firmly. It is very sensitive in operation, and responds to very slight differences of pressure.

The names of the parts are: 2, Body; 3, Cap Nut; 4, Valve; 5, Stem Valve; 6, Adjusting Spring; 7, Adjusting Nut.

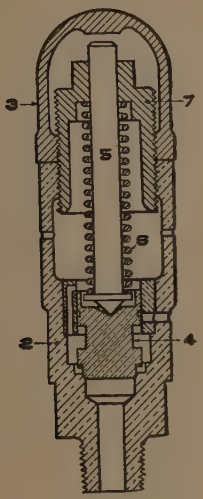


FIG. 309. SAFETY VALVE

Valve 4 is held to its seat by the compression of the spring 6 between the stem and adjusting nut 7. When the pressure below valve 4 is in excess of the force exerted by the spring, it raises, being guided in its movement by the brass bush in the body 2. Ports are drilled in this bush; one outward through the body to the atmosphere, and the other upward to the spring chamber.

Although only one of each of these is shown in the cut, there are eight of the first and two of the second. As the valve moves upward, its lift is determined by the stem 5 striking the cup nut 3. It closes the vertical ports connecting the valve and spring chambers and opens the lower ports to the atmosphere. As the air pressure below valve 4 decreases, and the tension of the spring forces the stem and valve downward, the valve gradually closes the lower ports to the atmosphere, and opens those between the valve and spring chambers. The discharge air pressure then has access to the spring chamber. This chamber is always connected to the atmosphere by two small holes through the body 2; the air from the valve chamber enters more rapidly than it can escape through these holes, causing pressure to accumulate above the valve, and close it with the "pop" action before mentioned.

The adjustment of this safety valve is accomplished by removing cap nut 3, and screwing up or down on adjusting nut 7. After the proper adjustment is made, cap nut 3 must be replaced and securely tightened, and the valve operated a few times. Particular attention must be given to the holes in the valve body to see that they are open, and that they are of the proper size, especially the two upper holes.

This safety valve should be adjusted for 53 pounds.

THE TYPE H AUTOMATIC BRAKE VALVE.

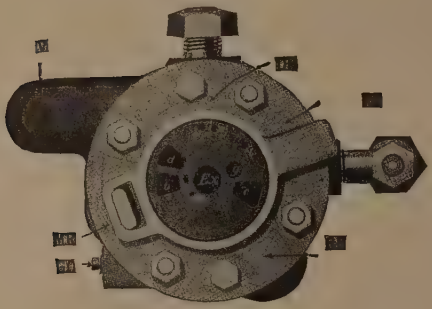
This Brake Valve, although modeled to a considerable extent upon the principles of previous valves, is necessarily different in detail, since it not only performs all the functions of such types, but also those absolutely

necessary to obtain all the desirable operating features of the Distributing Valve.

Fig. 310 is taken from a photograph of this brake valve, while Fig. 311 shows two views, the upper one being a plan view with section through the rotary-valve chamber, the rotary valve being removed; the lower one a vertical section. In these views the pipe connections are indicated.

FIG. 310. TYPE H BRAKE VALVE

Fig. 312 is a top view, showing the six positions of the brake-valve handle, which are, beginning at the extreme left, Release, Running, Holding, Lap, Service and Emergency.



ROTARY-VALVE SEAT.

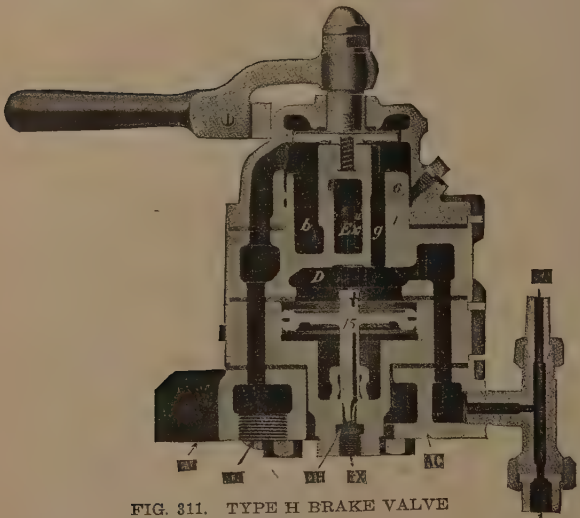


FIG. 311. TYPE H BRAKE VALVE

CONNECTIONS:

FV—Feed-Valve Pipe; MR—Main-Reservoir Pipe; GO—To Governor; DH—Double Heading Pipe; EX—Exhaust; AC—Application-Chamber Pipe; BP—Brake Pipe; GA—Duplex Air Gauge; ER—Equalizing Reservoir

Fig. 313 shows two views of this valve similar to those of Fig. 311, with the addition of a plan or top view of the rotary valve. Referring to the latter, *a, j* and *s* are ports extending directly through it, the latter connecting with a groove in the face; *f* and *k* are cavities in the valve

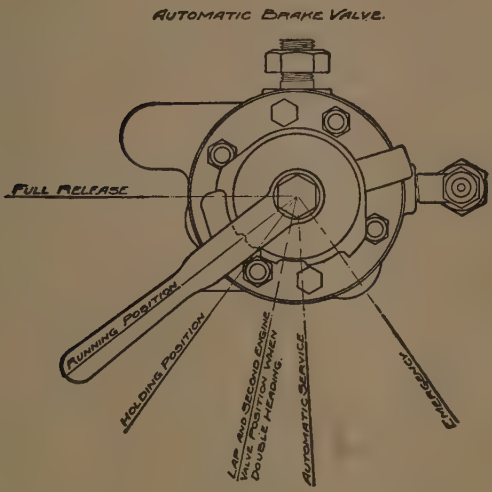


FIG. 312

face; *o* is the exhaust cavity; *x* is a port in the face of the valve connecting with *o; h* is a port in the face which passes over cavity *k* and connects with exhaust cavity *o; n* is a groove in the face. Referring to the ports in the rotary-valve seat, *d* leads to the feed-valve pipe; *b* and *c* lead to the brake pipe; *g* leads to chamber D; EX is the exhaust opening; *e* is the preliminary exhaust port lead-

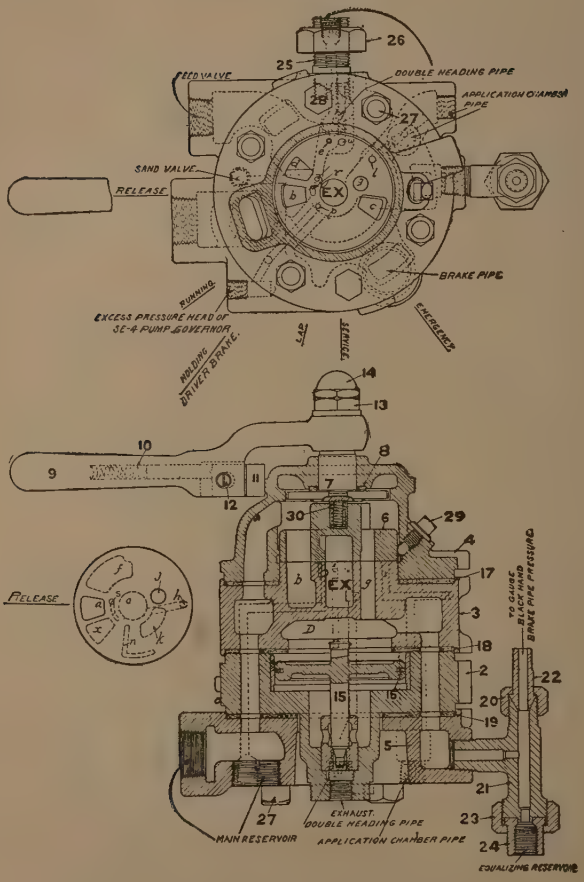


FIG. 313. AUTOMATIC BRAKE VALVE

ing to chamber D; *r* is the warning port leading to the exhaust; *p* is the port leading to the pump governor; *l* leads to the application-chamber pipe; *n* leads to the double-heading pipe.

In describing the operation of the brake valve, it will be more readily understood if the positions are taken up in the order in which they are most generally used, rather than their regular order as mentioned above.

RUNNING POSITION. This is the proper position of the handle to release the engine and tender brakes; also when the brakes are not being used, and the system is charged and ready for an application. In this position, cavity *f* in the rotary valve connects ports *b* and *d* in the valve seat, affording a large direct passage from the feed valve to the brake pipe, so that the latter will charge up as rapidly as the feed valve can supply the air, but cannot attain a pressure above that for which the feed valve is adjusted. Cavity *k* in the rotary valve connects ports *c* and *g* in the valve seat, so that chamber D, and the equalizing reservoir charge uniformly with the brake pipe, keeping the pressures on the two sides of the equalizing piston equal. Port *s* in the rotary valve registers with port *p* in the valve seat, permitting main-reservoir pressure, which is present at all times above the rotary valve, to pass to the excess-pressure head of the pump governor. Port *h* in the rotary valve registers with port *l* in the seat connecting the application chamber pipe to the exhaust cavity EX.

SERVICE POSITION. This position gives a gradual reduction of brake-pipe pressure to cause a service application. Port *h* in the rotary valve registers with port *s* in the valve seat, allowing air from chamber D and the

equalizing reservoir to escape to the atmosphere through cavities *o* in the rotary valve and EX in the valve seat. Port *e* is restricted so as to make the pressure in the equalizing reservoir, and chamber D fall gradually. As all other ports are closed, the fall of pressure in chamber D allows the brake-pipe pressure under the equalizing piston to raise it, and unseat the discharge valve, allowing brake-pipe air to flow to the atmosphere. When the pressure in chamber D is reduced the desired amount, the handle is moved to the *lap position,* thus stopping any further reduction in that chamber. Air will continue to discharge from the brake-pipe until its pressure has fallen to an amount a trifle less than that retained in chamber D, permitting the pressure in this chamber to force the piston downward and stop the discharge of brake-pipe air. It will be seen, therefore, that the amount of reduction in the equalizing reservoir determines that in the brake pipe, regardless of the length of the train.

LAP POSITION. This position is used while holding the brakes applied after a service application until it is desired either to make a further brake-pipe reduction, or to release them; also to prevent loss of main-reservoir pressure of the release of the brake in the event of a burst hose, a break-in-two, or the opening of the conductor's valve. Lap position is also used on all engines in a train that are not controlling the train brakes, as, with the handle in this position, port *h* in the rotary valve connects with port *u* in the seat. Therefore, when the double cut-out cock is turned to the position which cuts out the brake pipe, it makes a direct opening from port *i* in the distributing valve through the double-heading pipe to the atmosphere, and is the passage through which the air escapes from the application chamber when the automatic brakes are being released.

RELEASE POSITION. The purpose of this position is to provide a large and direct passage from the main reservoir to the brake pipe, to permit a rapid flow of air into the latter, to insure a quick release and recharging of the train brakes, but without releasing the engine and tender brakes.

Air at main-reservoir pressure flows through port *a* in the rotary valve to port *b* in the valve seat and to the brake pipe. At the same time, port *j* in the rotary valve registers with the equalizing port *g* in the valve seat, permitting main-reservoir pressure to enter chamber D above the equalizing piston.

In this position, port *s* in the rotary valve registers with warning port *r* in the seat and allows a small quantity of air to escape into the exhaust cavity EX, which makes sufficient noise to attract the engineer's attention to the position in which the valve handle is standing. If the handle is allowed to remain in this position, the brake system would be charged to main-reservoir pressure. To avoid this, the handle must be moved to Running or Holding Positions. The small groove in the face of the rotary valve which connects with port *s*, extends to port *p* in the valve seat, allowing main-reservoir pressure to flow to the excess-pressure head of the pump governor.

HOLDING POSITION. This position is so named because the locomotive brakes are held applied, as they are in release position, while the train brakes feed up to the feed-valve pressure. All ports register as in running position, except port *l*, which is closed.

Therefore, the only difference between Running and Holding Positions is, that in the former the application chamber is open to the atmosphere, while in the latter it is not.

EMERGENCY POSITION. This position is used when the most prompt and heavy application of the brakes is desired. Port *x* in the rotary valve registers with port *c* in the valve seat, making a large and direct communication between the brake pipe and atmosphere through cavity *o* in the rotary valve and EX in the valve seat. This direct passage causes a sudden and heavy discharge of brake-pipe pressure, causing the triple valves and distributing valve to go to the emergency position and apply the brake in the shortest possible time.

In this position the groove *n* in the rotary valve connects ports *g* and *l* in the valve seat, thereby allowing equalizing reservoir air to flow into the application chamber.

The oil plug 29 is placed in the top case 4, at a point to fix the level of the oil surrounding the rotary valve. Leather washer 8 prevents air in the rotary valve chamber from leaking past the rotary valve key to the atmosphere. Spring 30 keeps the rotary valve key firmly pressed against washer 8 when no main-reservoir pressure is present. The handle 9 contains a latch 11, which fits into notches in the top case, so located as to indicate the different positions of the brake valve handle. The spring 10 back of the latch forces the latter against the body with sufficient pressure to distinctly indicate when the handle arrives at each position.

To remove the brake valve take off nuts 27, thus allowing it to come away without disturbing the pipe bracket, or breaking any pipe joints. To take the valve proper apart, remove cap screws 28.

The brake valve should be located so that the engineer can operate it from his usual position, while looking forward or back out of the side-cab window, and in such

a manner that the handle will not meet with any obstruction throughout its entire movement.

The oil around the rotary valve furnishes thorough lubrication. Valve oil should be used for this purpose.

Fig. 313 shows all the principal parts, the proper names of each being as follows: 2, Bottom Case; 3, Rotary-Valve Seat; 4, Top Case; 5, Pipe Bracket; 6, Rotary Valve; 7, Rotary-Valve Key; 8, Key Washer; 9, Handle; 10, Handle-Latch Spring; 11, Handle Latch; 12, Handle-Latch Screw; 13, Handle Nut; 14, Handle Lock Nut; 15, Equalizing Piston; 16, Equalizing-Piston Packing Ring; 17, Valve-Seat Upper Gasket; 18, Valve-Seat Lower Gasket; 19, Pipe-Bracket Gasket; 20, Small Union Nut; 21, Brake-Valve Tee; 22, Small Union Swivel; 23, Large Union Nut; 24, Large Union Swivel; 25, Bracket Stud; 26, Bracket-Stud Nut; 27, Bolt and Nut; 28, Cap Screw; 29, Oil Plug; 30, Rotary-Valve Spring.

THE INDEPENDENT BRAKE VALVE.

Fig. 314 illustrates this valve, which is of the rotary type. Fig. 315 shows a vertical section through the center of the valve, and a horizontal section through the valve body, with the rotary valve removed, showing the rotary valve seat. Fig. 316 shows this valve similarly to Fig. 315, with the addition of a top view of the rotary valve. In these views, the pipe connections and positions of the handle are indicated. Port *b* in the seat leads to the supply connection from the main reservoir through the Reducing Valve. Port *c* leads to that portion of the application-chamber pipe which connects to the automatic-brake valve. Port *d* leads to that portion of the application-chamber pipe which connects the dis-

tributing valve. Port *h*, in the center, is the exhaust port leading directly to the atmosphere. Exhaust cavity *g* in the rotary valve is always in communication with exhaust port *h*. Groove *e* in the face of the valve communicates at one end with a port through the valve. This groove is always in communication with supply port *b*, and through the opening just mentioned air is admitted

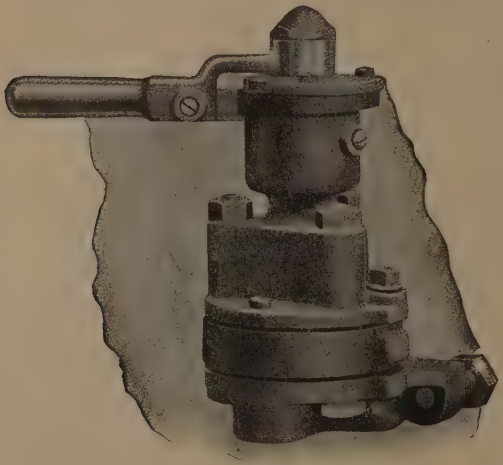


FIG. 314. THE INDEPENDENT BRAKE VALVE

to the chamber above the rotary valve, thus keeping it to its seat. Port *f* in the rotary valve consists of two circular openings in the face joined by a cylindrical passage over the top of cavity *g*.

RUNNING POSITION. This is the position that the independent brake valve should be carried in at all times

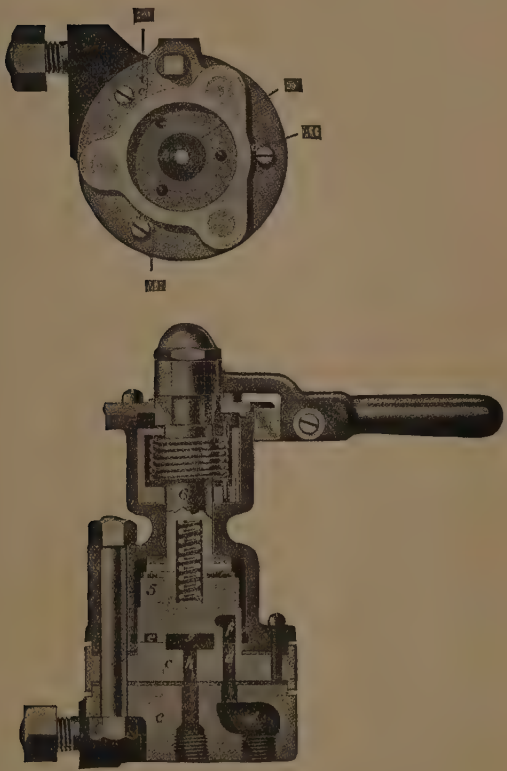


FIG. 315. INTERIOR VIEW OF THE INDEPENDENT BRAKE VALVE

CONNECTIONS:

BV—Application-Chamber Pipe to Automatic Brake Valve; EX—Exhaust; AC—Application-Chamber Pipe to Distributing Valve; MR—Reducing-Valve Pipe

when the independent brake is not in use. Port *f* in the rotary valve connects ports *c* and *d* in the valve seat, thus establishing communication between the application chamber of the distributing valve and port *l* of the automatic brake valve. Therefore, it will be seen that if the automatic brake valve is in running position, and the independent brakes applied, they can be released by returning the independent valve to running position.

Service Position. To apply the independent brakes, move the brake valve to the application position; groove *e* connects ports *b* and *d*, allowing air to flow to the application chamber of the distributing valve. Since the supply pressure to this valve is fixed by the regulation of the reducing valve to 45 pounds, this is the maximum cylinder pressure that can be obtained.

Lap Position. This position is used to hold the independent brakes applied after the desired cylinder pressure is obtained, at which time all communication between operating ports is closed.

Release Position. This position is used to release the pressure from the application chamber when the automatic brake valve is not in running position. In this position, the offset in cavity *g* registers with port *d*, allowing pressure in the application chamber to flow through ports *d*, *g* and *h* to the atmosphere.

In order to prevent leaving the handle in the release position, and thereby make it impossible to operate the locomotive brakes by the automatic brake valve, spring 9 automatically returns handle 15 from the release to the running position.

The purpose of the oil plug 20 is the same as that described in the automatic brake valve.

The location of this valve should be governed by the

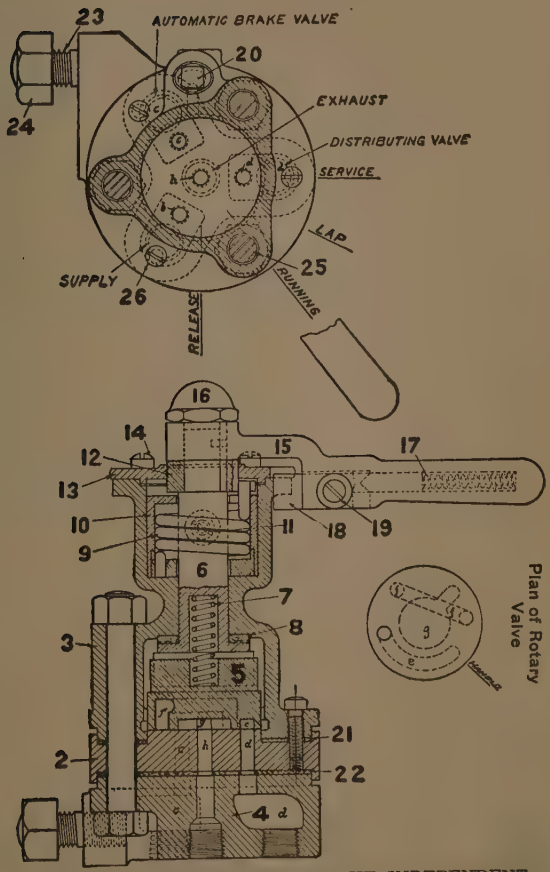


FIG. 316. INTERIOR VIEWS OF THE INDEPENDENT BRAKE VALVE

same considerations as those mentioned concerning the automatic brake valve. The names of its parts are as follows, referring to Fig. 316.

2, Rotary-Valve Seat; 3, Valve Body; 4, Pipe Bracket; 5, Rotary Valve; 6, Rotary-Valve Key; 7, Rotary-Valve Spring; 8, Key Washer; 9, Return-Spring; 10, Return-Spring Casing; 11, Casing Screw; 12, Return-Spring Clutch; 13, Cover; 14, Cover Screw; 15, Handle; 16, Handle Nut; 17, Latch Spring; 18, Latch; 19, Latch Screw; 20, Oil Plug; 21, Upper Gasket; 22, Lower Gasket; 23, Bracket Stud; 24, Bracket-Stud Nut; 25, Bolt and Nut; 26, Cap and Screw.

THE FEED VALVE.

This valve, Fig. 317, is a slide-valve feed valve of an improved type, and with this equipment is connected to a pipe bracket located in the piping between the main reservoir and the automatic brake valve, receiving its supply of air from the main-reservoir pipe, and delivering it into the feed-valve pipe. It is for the purpose of controlling brake-pipe pressure when the automatic brake valve handle is in running or holding positions.

Figs. 318 and 319 are diagrammatic views of the valve and pipe bracket having the ports and operating parts in one plane to facilitate description. It consists of two sets of parts, the supply and regulating. The supply parts, which control the flow of air through the valve, consist of the supply valve 10, and its spring 11; the supply-valve piston 8 and its spring 6. The regulating parts consist of the regulating valve 13, regulating-valve spring 14, diaphragm 15, diaphragm spindle 17, regulating handle 23. Main-reservoir air enters through port

a, *a* to the supply-valve chamber B, forcing supply-valve piston 8 to the left, compressing piston spring 6 and causing supply valve 10 to open port *c*, permitting the air to pass through ports *c* and *d* to the feed-valve pipe at delivery, and through port *c* to diaphragm chamber L.

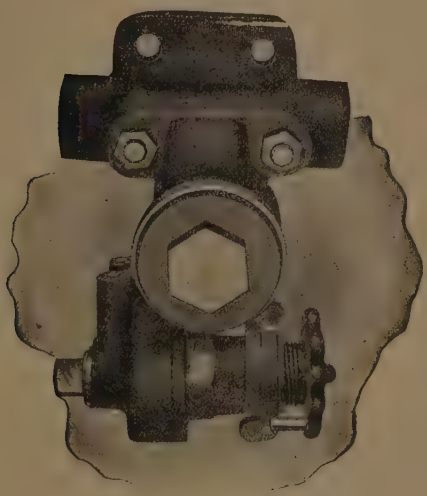


FIG. 317. FEED VALVE

At the same time air flows through port *f* in supply-valve piston 8 to chamber G, and through port *h* to regulating-valve chamber H. As regulating-valve 13 is raised from its seat, it will flow through port *k* to chamber L. When the feed-valve-pipe pressure, which is always present in chamber L against the dia-

phragm, exceeds the pressure of regulating spring 18, the diaphragm will yield and permit the regulating valve 13 to be forced to its seat, closing port *k* and cutting off

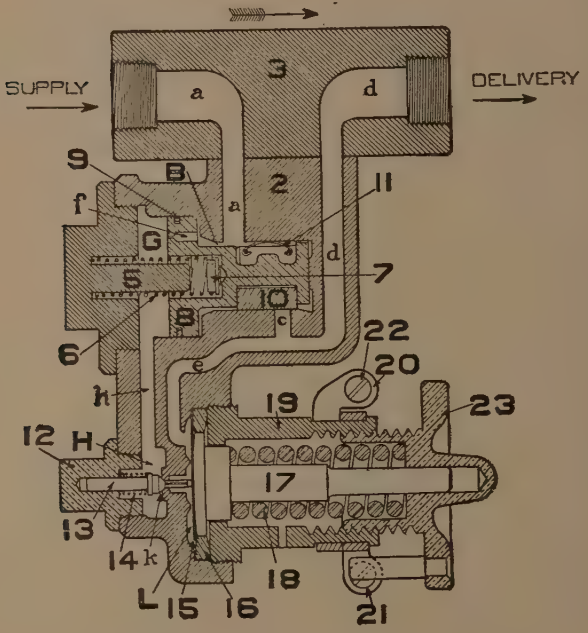


FIG. 318. DIAGRAM OF FEED VALVE, CLOSED

any further flow of air from chamber G. As the air which continues to flow through port *f* will quickly equalize the pressure on both sides of piston 8, spring 6 will

force the piston to the right, moving supply valve 10 and closing port *c*, thereby cutting off communication between the supply and the feed-valve pipe.

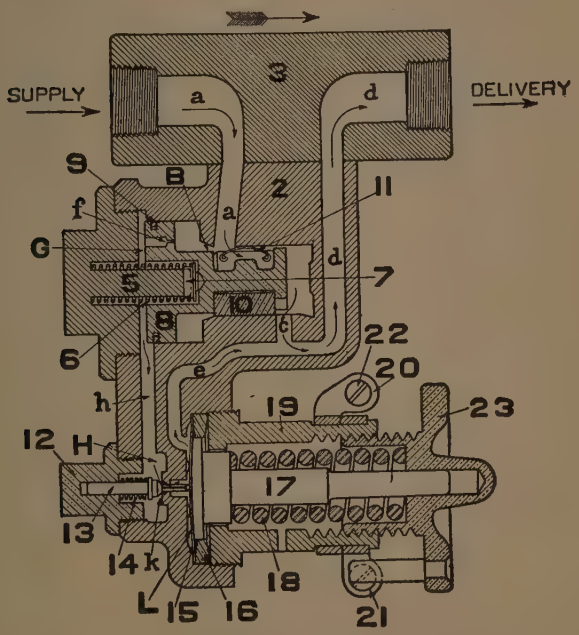


FIG. 319. DIAGRAM OF FEED VALVE, OPEN

When the pressure in the feed-valve pipe falls below that for which the valve is adjusted, regulating spring 18 will force the diaphragm forward, unseat regulating valve

13, and permit the accumulated air pressure in chamber G to escape through port *h*, chamber H, and port *k* to chamber L. This allows main-reservoir pressure in chamber B to force the supply valve piston 8 to left, and open port *c*, which again permits air to pass to the feed-valve pipe until its pressure has been restored to the proper amount. Since this feed valve has a duplex adjusting arrangement, it eliminates the necessity of the two feed valves in high, and low pressure service, as the turning of handle 23 until its pin strikes stops 20, or 21 changes the regulation from one predetermined brake-pipe pressure to another.

To adjust this valve, slacken screw 22, which allows stops 20 and 21 to turn around spring box 19. Adjusting handle 23 should be turned until the valve closes at the lower brake pipe pressure desired, when stop 21 should be brought in contact with the handle pin, at which point it should be securely fastened by tightening screw 22. Adjusting handle 23 should then be turned until the higher adjustment is obtained, when stop 20 is brought in contact with the handle pin and securely fastened.

The names of the parts shown in the diagram, Figs. 318 and 319, are as follows: 2, Valve Body; 3, Pipe Bracket; 5, Cap Nut; 6, Piston Spring; 7, Piston-Spring Tip; 8, Supply-Valve Piston; 9, Piston Packing Ring; 10, Supply Valve; 11, Supply-Valve Spring; 12, Regulating-Valve Cap; 13, Regulating Valve; 14, Regulating-Valve Spring; 15, Diaphragm; 16, Diaphragm Ring; 17, Diaphragm Spindle; 18, Regulating Spring; 19, Spring Box; 20, Upper Stop; 21, Lower Stop; 22, Stop Screw; 23, Adjusting Handle.

REDUCING VALVE.

Fig. 320 is a photograph of the exterior of this valve connected to its pipe bracket, the construction and opera-

FIG. 320. REDUCING VALVE

tion of which is the same as the feed valve just described, with the exception of the adjusting feature, this valve being designed for single adjustment only.

THE PUMP GOVERNOR.

Fig. 321 shows a sectional view of this governor in its normal position. By reference to the piping diagram in Fig. 295 it will be noted that the connection B leads to the boiler; P to the air pump; MR to the main reservoir;

ABV to the automatic brake valve; FVP to the feed-valve pipe; W is the waste-pipe connection. Steam enters at B and passes by steam valve 26 to the connection P and to the pump. Air from the main reservoir flows

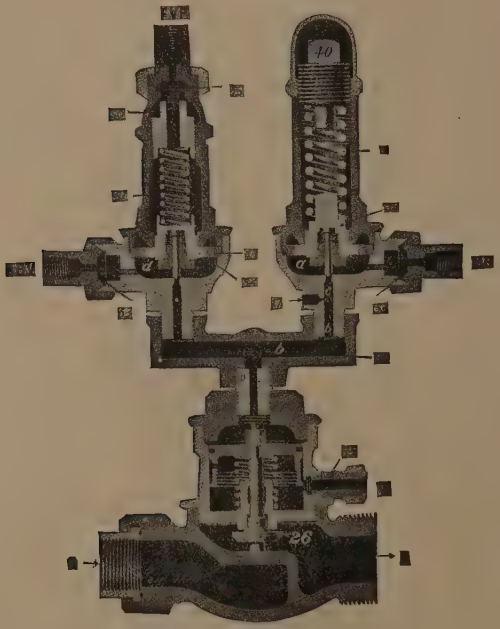


FIG. 321. PUMP GOVERNOR

through the automatic brake valve to the connection marked ABV into chamber *d* below diaphragm 52. Air from the feed-valve pipe enters at the connection FVP and passes to the chamber above the diaphragm, adding

to the pressure of regulating spring 51 in holding it down. As this spring is adjusted to a compression of about 20 pounds, the diaphragm will be held down until the main reservoir-pressure in chamber *d* exceeds the feed-valve pipe pressure by this amount. At such time, diaphragm 52 will raise, unseating its pin valve, and allow air to flow through port *b* to the chamber above the governor piston, forcing it downward, compressing its spring and seating steam valve 26. When main-reservoir pressure in chamber *d* is reduced, the combined spring and air pressures above the diaphragm force it down, seating its pin valve. The pressure in port *b*, and the chamber above the governor piston, which is always able to escape a little from the vent port *c*, will then escape to the atmosphere and allow the piston spring, and steam pressure below valve 26, to raise it, and the governor piston to the position shown. The connection from the main reservoir to chamber *d* is open only when the automatic brake-valve handle is in release, running or holding positions; in the other positions it is closed, at which times this governor head is cut out of action. The connection marked MR in the maximum pressure head is always in communication with the main reservoir, so that when the excess pressure head is cut out by the brake valve, this head controls the pump. When main-reservoir pressure in chamber *a* exceeds the compression of adjusting spring 41, diaphragm 42 will raise its pin valve and allow air to flow through port *b* to the chamber above the governor piston, controlling the pump as above described.

As each governor head has a vent port *c*, from which air escapes whenever pressure is present in port *b*, to avoid an unnecessary waste of air, one of these should be plugged.

To adjust this governor, remove the cap nut and turn adjusting nut 50 until the compression of spring 51 is equal to the excess of pressure desired.

QUESTIONS

949. In what respect does the new ET. Locomotive brake equipment differ materially from the standard automatic and straight air brake?

950. Can the ET. equipment be applied to any locomotive; no matter what kind of service?

951. Mention one of the principal advantages in connection with the design of the valves.

952. What are the three important advantages connected with its operation?

953. What can be said regarding the manipulation of the ET. brake, and the automatic and straight air brake?

954. In what position should the handle be, when not in use?

955. When it is desired to apply the locomotive and train brakes, how must the automatic brake valve handle be moved?

956. Describe the method of releasing the train brakes.

957. Describe the method of making an emergency application.

958. In order to make a smooth and accurate, two application passenger stop, what should be done?

959. Describe the proper method of making and releasing an independent application.

960. How should the independent brake be operated, when handling long trains on the road, or in switching service?

961. How may the engine brakes only be released, and still leave the train brakes applied?

962. What should be done with the train brakes before detaching the engine?

963. Should the automatic brakes be used to hold a train or engine standing on a grade, for any length of time?

964. What is the safest way to hold a train standing on a grade?

965. Describe the proper method of stopping a descending train, and then holding it with the independent brake.

966. In what position should the independent brake valve handle be left when the engine is standing at a coal chute or water plug?

967. In what position should the handle of the automatic brake valve be placed in case of an accidental application—such as a bursted hose, or break in two of train?

968. In case there are two or more engines in a train, what should be done with the air equipment of each one, except the one from which the brakes are being handled?

969. What should be done with the brake equipment on the engine, before leaving the roundhouse?

970. Name the various parts of the equipment, and the purpose of each.

971. Name the different parts of the piping appertaining to the ET equipment.

972. What are the functions of the main reservoir cut-out cock?

973. In what two ways does the automatic brake valve receive air from the main reservoir?

974. How many connections has the distributing valve?

975. What are the functions of the first three of these connections?

976. For what purpose are the other two?

977. What is the important feature of the ET brake equipment?

978. Describe briefly what takes place within the distributing valve during an independent application.

979. What causes independent lap?

980. Between what two pressures does the application piston of the distributing valve vibrate?

981. How is the pressure maintained in the brake cylinders during an application?

982. How is independent release accomplished?

983. How may independent lap be again resumed?

984. What parts are brought into action during automatic operation?

985. Describe in general terms what occurs within the distributing valve during a service application of the automatic brake.

986. Upon what does the amount of pressure in the application chamber of the distributing valve depend?

987. What causes the position known as service lap?

988. Does the pressure maintaining feature also apply to automatic application?

989. Are the engine brakes released when the automatic brake valve is placed in release position?

990. What, then, must be done in order to release the engine brakes?

991. What takes place within the distributing valve during an emergency application?

992. What pressures are carried for high speed brake service?

993. Under these conditions, what pressure is attained in the application chamber?

994. What conditions are necessary to cause the parts of the valve to assume the position known as emergency lap?

995. What is the purpose of the double-heading pipe connection?

996. Describe the action of the safety valve.

997. How is this valve adjusted, and for what pressure?

998. In what respect does type H automatic brake valve differ from previous types?

999. When should the handle be kept in running position?

1000. What does service position give?

1001. For what purpose is lap position used?

1002. What is the purpose of release position?

1003. What results follow, when the valve is placed in holding position?

1004. Explain the difference between running and holding position.

1005. When is emergency position used?

1006. Of what type is the independent brake valve?

1007. In what position should this valve be carried when not in use?

1008. Describe the service position of this valve.

1009. When is lap position used for the independent brake valve?

1010. When is release position used?

1011. What type of valve, and for what purpose is the feed valve?

1012. Describe the construction and operation of the reducing valve.

1013. Describe the construction and operation of the pump governor.

1014. What is the "Dead Engine Feature"?

1015. Of what parts does it consist?

1016. How is the air for operating the brakes on a dead engine supplied?

1017. Describe briefly the route that the air takes under such conditions.

1018. What is the function of the strainer?

THE "DEAD ENGINE" FEATURE.

The "Dead Engine" feature shown in Fig. 295 is for the operation of the locomotive brakes when the pump on a locomotive in a train is inoperative through being broken down, or by reason of no steam. Fig. 322 shows the combined strainer, check valve, and choke fitting. As these parts are not required at other times, a cut-out cock is provided. This cock should be kept closed except under the conditions just mentioned. The air for operating the brakes on such a locomotive must then be supplied through the brake pipe from the locomotive operating the train brakes.

FIG. 322. COMBINED AIR STRAINER AND CHECK VALVE

With the cut-out cock open, air from the brake pipe enters at BP, Fig. 322, passes through the curled hair strainer, lifts check valve 4, held to its seat by a strong spring, passes through the choke bushing, and out at MR to the main-reservoir, thus providing pressure for operating the brakes on this locomotive. The double-

heading cock should be closed, and the handle of each brake valve should be in running position. Where absence of water in the boiler, or other reason, justifies keeping the maximum braking power of such a locomotive lower than the standard, this can be accomplished by reducing the adjustment of the safety valve on the distributing valve. It can also be reduced at will by the independent brake valve.

The strainer protects the check valve and choke from dirt. Spring 2 over the check valve insures this valve seating and, while assuring an ample pressure to operate the locomotive brakes, keeps the main-reservoir pressure somewhat lower than the brake-pipe pressure, thereby reducing any leakage from the former. The choke prevents a sudden drop in brake-pipe pressure and the application of the train brakes, as would otherwise occur with an uncharged main reservoir cut in to a charged brake pipe. In this, it operates similarly to the feed groove in a triple valve.

THE TYPE "K" FREIGHT TRIPLE VALVE.

Modern conditions have created new braking problems. The old and well-known (Type H) quick-action freight triple valve was designed to meet the requirements of the time when 50-car trains, 30-ton capacity cars, and moderate speeds were maximum conditions. But the increased train lengths, speeds, and car capacities of the present day, have demanded certain modifications to meet these, and anticipated, requirements.

The Westinghouse Air Brake Company has developed and perfected a new Quick-Action Freight Triple Valve, designated as Type "K," which facilitates train move-

ments, increases the factor of safety in handling trains, and reduces damage to lading and equipment, in so far as they are affected by air-brake operation.

The K triple valve embodies every feature of the old type, and in addition three new ones called the *Quick-Service, Retarded Release* and *Uniform Recharge.* It not only works in perfect harmony with the old valves, but greatly improves the action of the latter when they are mixed in the same train. They have many parts in common, are interchangeable, and the old can be converted into the new without the loss of many parts.

The *Quick-Service* Feature, which produces a quick serial operation of the brakes in service applications, has been obtained by utilizing the well known principle of quick-action in emergency applications, by which each triple valve augments the brake-pipe reduction by discharging brake-pipe air into its brake cylinder. The essential difference is that in emergency, the maximum braking power is always obtained with both the old and new valves, while with the new valve, the power of its quick-service application is always under complete control, and is governed by the reduction made at the brake valve. The result is that the quick-service feature insures the prompt and reliable response of every brake; eliminates the undesirable use of emergency applications where a flag, an unforeseen danger ahead, or the need of making an accurate stop, frequently necessitates such an application with the old standard freight-brake equipment; reduces the possible loss of air due to flowing back through the feed grooves from the auxiliary reservoir to the brake pipe, or by the leakage grooves in the cylinders; and gives a more uniform application of the brakes throughout the train.

The *Retarded-Release* Feature, which insures practically a *simultaneous* release of all brakes, has been effected by automatically restricting the exhaust of air from the brake cylinders at the head end of the train, and allowing all others to release freely. To obtain this result requires merely the usual correct method of operating the brake valve, the retarded release being due to the quick and considerable rise in brake-pipe pressure which the release position of the brake valve can cause for about 25 or 30 cars from the locomotive.

The *Uniform Recharge* of the auxiliary reservoirs throughout the train is obtained by the fact that when the triple valve is in retarded-release position, the charging ports between brake pipe and auxiliary reservoir are automatically restricted. As long as the release of brake-cylinder exhaust is retarded, the recharge is restricted, and since the one feature depends upon the other, the restricted recharge operates only on the first twenty-five or thirty cars back of the engine, the remaining brakes recharging normally, thus insuring practically a simultaneous recharge of all brakes in the train. This feature not only avoids the overcharge of the auxiliary reservoirs on the front cars and the subsequent undesired reapplication of their brakes, but by drawing less air from the brake pipe permits the increase in brake-pipe pressure to travel more rapidly to the rear for releasing and recharging those brakes.

The new valve is at present manufactured in two sizes, the "K-1" for use with 8-inch freight-car brake cylinders, corresponding with the H-1 (F-36), and the "K-2" with 10-inch freight-car brake cylinders, corresponding with the H-2 (H-49). The K-1 will bolt to the same reservoir as the F-36, and the K-2 as the H-49. Each valve

is marked with its designation on the side of the valve body, and the K-2 may be distinguished from the K-1 by the fact that it has *three,* as compared with *two,* bolt holes in the reservoir flange. Also, in order to distinguish the type K valves from the old standard type, their exterior being similar when they are attached to the

FIG. 323. THE TYPE "K" FREIGHT TRIPLE VALVE

auxiliary reservoir, a lug is cast on the top of the valve body, as shown in Fig. 323. This enables anyone to locate them at once.

Fig. 324 is a vertical cross section of this valve, and the names of the various parts are as follows:

2, Valve Body; 3, Slide Valve; 4, Piston; 5, Piston-Packing Ring; 6, Slide-Valve Spring; 7, Graduating Valve; 8, Emergency Piston; 9, Emergency-Valve Seat; 10, Emergency Valve; 11, Emergency-Valve Rubber Seat; 12, Check-Valve Spring; 13, Check-Valve Case; 14, Check-Valve-Case Gasket; 15, Check Valve; 16, Air Strainer; 17, Union Nut; 18, Union Swivel; 19, Cylinder Cap; 20, Graduating-Stem Nut; 21, Graduating Stem;

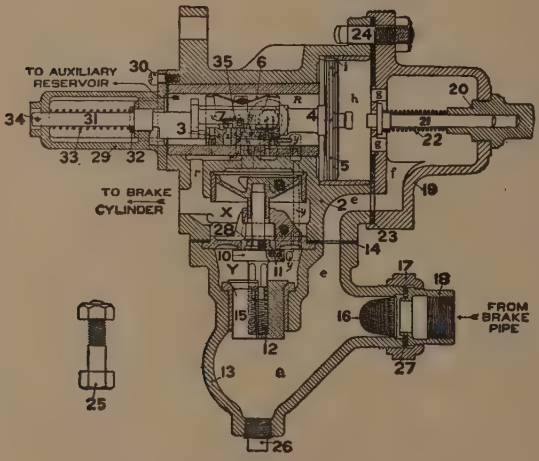


FIG. 324. THE K-2 TRIPLE VALVE

22, Graduating Spring; 23, Cylinder-Cap Gasket; 24, Bolt and Nut; 25, Triple-Valve Cap Screw; 26, Drain Plug; 27, Union Gasket; 28, Emergency-Valve Nut; 29, Retarding-Device Bracket; 30, Retarding-Device Screw; 31, Retarding-Device Stem; 32, Retarding-Device

Washer; 33, Retarding-Device Spring; 34, Retarding-Device-Stem Pin; 35, Graduating-Valve Spring.

Figure 325 shows the relative position of the ports and cavities in the slide valve, graduating valve, and slide-valve seat of the K-2 Triple Valve. As it is difficult to show all of these in a single section, diagrammatic cuts of the valve in each of the principal positions have been used, all ports and passages having been so arranged as to place them in one plane. In preparing these cuts, the actual proportion, and mechanical construction of the valve has been disregarded for the purpose of making the connections of ports, and operation, more easily understood.

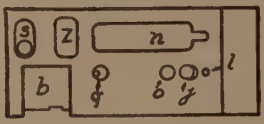
EXPLANATION OF FIGURES 324 AND 325.

Referring to Figure 324, the branch from the brake pipe connects at union swivel 18. The retarding-device bracket 29 projects into the auxiliary reservoir, and by its construction free communication exists between the auxiliary reservoir and chamber R, in which the slide-valve 3 and graduating valve 7 operate. The retarding-device stem 31, through its extension into chamber R, and the action of its spring 33, forms the stop against which the stem of piston 4 strikes when it moves to the release position (from right to left in the cut, it being shown in full-release position).

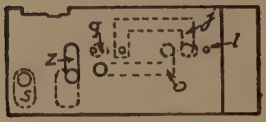
The opening marked "To Brake Cylinder" comes opposite one end of the tube which leads through the auxiliary reservoir to the brake cylinder, when the valve is bolted in place on the end of the auxiliary reservoir. This opening in the triple valve leads to chamber X

FACE VIEW

GRADUATING VALVE.

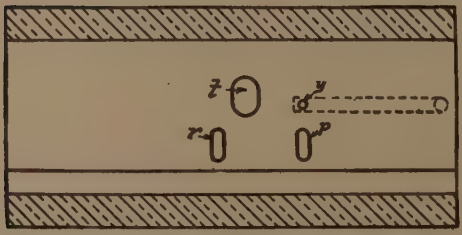


FACE VIEW



TOP VIEW

SLIDE VALVE.



SLIDE VALVE BUSH.

FIG. 325. SLIDE VALVE, GRADUATING VALVE, AND SLIDE-VALVE SEAT OF K-2 TRIPLE VALVE

over the emergency valve 10, and under the emergency piston 8. Also, it leads through port *r* to the seat under slide valve 3 (Fig. 325). The emergency piston 8 and the parts below it are the same as in the older quick-action freight triple valve. Port *y* (shown by dotted lines) connects chamber Y, between check valve 12 and emergency valve 10, with port *y* in the valve seat (Fig. 325).

Port *t* connects the slide-valve seat with the chamber above emergency piston 8. Port *p* is the exhaust port to the atmosphere. Port *j* in the slide valve begins at the face, as shown by the top view, Fig. 325, and passes around other ports in the valve to a smaller opening in the top. (NOTE:—This port *j* does not exist in the K-1 Triple Valve, as will be explained later.) Port *o* is similarly arranged, except that openings in top and bottom are alike in size. Port *q* runs directly through the slide valve, but is smaller at the top than at the face of the valve, and the smaller part is out of center with the larger part. Ports *s* and *z* run through the valve and connect with cavities in the face; port *z* also has a cavity at the top.

The face view of the graduating valve shows that it has a small cavity *v*. This valve is of the slide-valve type, and it seats on the top of the slide valve, where it controls the upper ends of ports *z*, *q*, *o* and *j*. The purpose of the cavity *v* is to connect the upper ends of ports *o* and *q* in a service application, as explained in detail later.

As shown by the face view of the slide valve, *n* is a long cavity having a narrow extension at the right hand end. This cavity connects the ports through which the air escapes from the brake cylinder in releasing. Port

b is cut diagonally from the face till it just cuts into the edge, at the top of the slide valve. It admits auxiliary-reservoir pressure to port *t* in an emergency application.

With this explanation, and by occasional reference from the diagrammatic views, to those in Fig. 325, the same ports being lettered alike, a clear understanding will be obtained of both the operation and actual arrangement of ports of the triple valves.

FULL RELEASE AND CHARGING POSITION.

Fig. 326 is a diagrammatic view of the triple valve in this position. Air from the brake pipe flows through passage *e*, cylinder cap *f*, and ports *g* to chamber *h*; thence through feed groove *i*, now open, to chamber R above the slide valve, which is always in free communication with the auxiliary reservoir. The feed groove *i* is of the same dimension as that of the old standard H-1 (F-36) triple valve, which is designed to properly charge the auxiliary reservoir of an 8-inch brake cylinder, and prevent any appreciable amount of air from feeding back into the brake pipe from the auxiliary reservoir during an application. For this reason, the feed groove of the K-2 triple valve is made the same size as the K-1, so that it is necessary in the K-2 triple, to increase the charging port area, through which the air can feed into the auxiliary reservoir, sufficiently to enable it to handle the greater volume of the auxiliary reservoir of a 10-inch brake cylinder. In order to do this, the small port *j* is added to the slide valve of the K-2 triple valve only; this port registers with port *y* in the slide-valve seat, when in the full release position. Air then passes from chamber Y, through ports *y* and *j* to chamber R, and the aux-

iliary reservoir. Brake-pipe air in *a* raises check valve 15 and supplies chamber Y with air as fast as it is required. Port *j* is so proportioned that the rate of charging the auxiliary reservoir of a 10-inch brake cylinder is made practically the same as that of the 8-inch, which in full

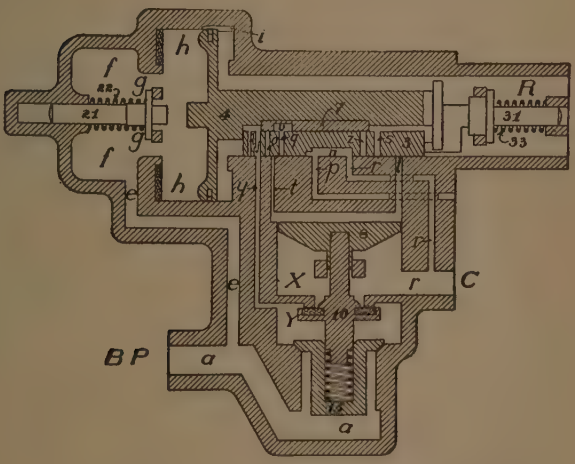


FIG. 326. FULL-RELEASE AND CHARGING POSITION

release is fed through the feed groove *i* only. In the following description, the K-2 triple valve only is referred to; the operation of the K-1 is exactly the same except for the absence of port *j*.

Air flows from the brake pipe to the auxiliary reservoir until their pressures become equal, when the latter is then fully charged.

QUICK-SERVICE POSITION.

To make a service application of the brakes, air pressure is gradually reduced in the brake pipe, and thereby in chamber *h*. As soon as the remaining pressure in the

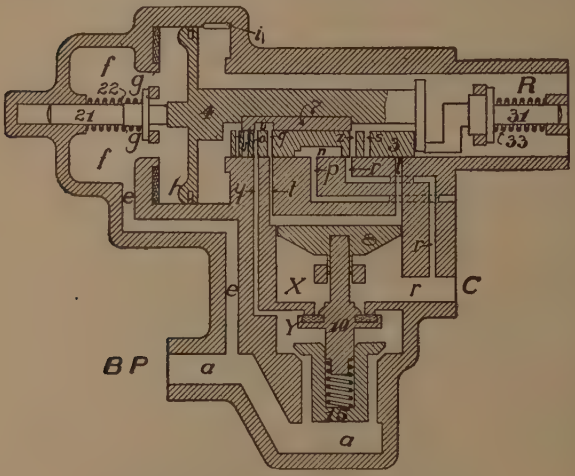


FIG. 327. QUICK SERVICE POSITION

auxiliary reservoir and chamber R becomes enough greater than that in chamber *h*, to overcome the friction of the piston 4 and graduating valve 7, these two move to the left until the shoulder on the end of the piston stem strikes against the right-hand end of the slide valve, when it also is moved to the left until the piston strikes the graduating stem 21, which is held in its place by the compression of the graduating spring 22. The parts of the valve are then in the position shown in Fig. 327.

The first movement of the graduating valve closes the feed groove *i*, preventing air from feeding back into the brake pipe from the auxiliary reservoir, and also opens the upper end of port *z* in the slide valve, while the movement of the latter closes the connection between port *r* and the exhaust port *p*, and brings port *z* into partial registration with port *r*, in the slide valve seat. Auxiliary-reservoir pressure then flows through port *z* in the slide valve, and port *r* in the seat to the brake cylinder.

At the same time, the first movement of the graduating valve connected the two ports *o* and *q* in the slide valve, by the cavity *v* in the graduating valve, and the movement of the slide valve brought port *o* to register with port *y* in the slide-valve seat, and port *q* with port *t*. Consequently, the air pressure in chamber Y flows through ports *y*, *o*, *v*, *q* and *t*, thence around the emergency piston 8, which fits loosely in its cylinder, to chamber X and the brake cylinder. When the pressure in chamber Y has reduced below the brake-pipe pressure remaining in *a*, the check valve raises, and allows brake-pipe air to flow by the check valve and through the ports above mentioned to the brake cylinders. The size of these ports is so proportioned that the flow of air from the brake pipe to the top of emergency piston 8, is not sufficient to force the latter downward, and thus cause an emergency application, but at the same time takes considerable air from the brake pipe, thus increasing the rapidity with which the brake-pipe reduction travels through the train.

With the ordinary quick action triple valve in a service application, all of the brake-pipe reduction has to be made at the brake valve, and the resulting drop in pressure passes back through the train at a rate depend-

ing on its length, size of brake pipe, number of bends and corners, etc., which cause friction and resistance; also a much heavier application of head than of rear brakes is caused at the beginning of the application, thereby running the slack in, which is liable at low speeds to be followed by the slack running out suddenly when the rear brakes do apply, causing loss of time and difficulty in making quick slow downs and accurate stops, and, with very long trains, results in such serious losses through leakage grooves, and feed grooves as to lose much braking power and even prevent some brakes from applying. With this new triple valve, only a small part of the reduction is made at the brake valve, while each triple acts momentarily as a brake valve to increase the reduction under each car, thereby rendering the resistance and friction in the brake pipe of much less effect, and hastening the application throughout the train. This is called the "Quick-Service" feature, and by means of it the rapidity of a full service application on a 50-car train is increased about fifty per cent. The rapid reduction of brake-pipe pressure moves the main piston 4 quickly to the service position, and cuts off any flow back from the auxiliary reservoir through the feed groove to the brake pipe; it rapidly drives the brake-cylinder piston beyond the leakage groove, and prevents loss of air through it; and yet permits applying with as moderate a brake force as desired. It also greatly reduces the brake-pipe reduction necessary at the brake valve for a certain brake-cylinder pressure, due to the fact (1) that part of the reduction takes place at each triple valve, and (2) that the air taken from the brake pipe into the brake cylinder gives a little higher pressure than if the auxiliary-reservoir pressure alone were admitted, thus re-

quiring a smaller brake-pipe reduction for the same cylinder pressure.

FULL-SERVICE POSITION.

With short trains, the brake-pipe volume, being comparatively small, will reduce more rapidly for a certain reduction at the brake valve than with long trains.

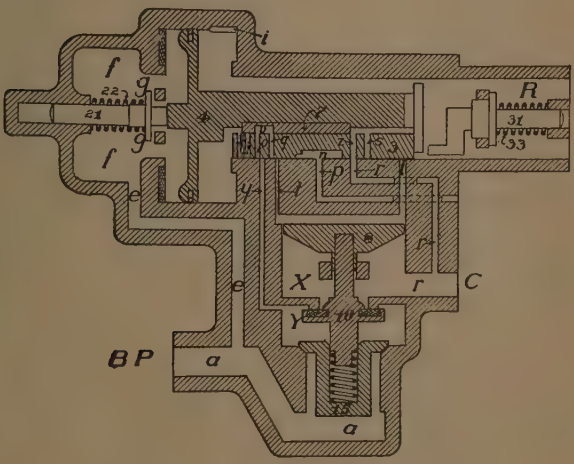


FIG. 328. FULL SERVICE POSITION

Under such circumstances the added reduction at each triple valve by the quick-service feature, might bring about so rapid a brake-pipe reduction as to cause quick action and an emergency application, when only a light application was intended. (The emergency application is explained later.) But this is automatically prevented

by the triple valve itself. From Fig. 327 it will be noted that in the quick-service position, port *z* in the slide valve and port *r* in the seat do not fully register. Nevertheless, the opening is sufficient to allow the air to flow from the auxiliary reservoir to the brake-cylinder with sufficient rapidity to reduce the pressure in the auxiliary reservoir as fast as the pressure is reducing in the brake pipe, when the train is of considerable length. But if the brake-pipe reduction is more rapid than that of the auxiliary, the difference in pressures on the two sides of piston 4 soon becomes sufficient to slightly compress the graduating spring, and move the slide valve to the position shown in Fig. 328, called *"Full Service."* In this position, quick service port *y* is closed, so that no air flows from the brake pipe to the brake cylinder; the brake-pipe reduction being sufficiently rapid, there is no need of the additional quick-service reduction, so the triple valve cuts it out. Also, ports *z* and *r* are fully open, and allow the auxiliary-reservoir pressure to reduce more rapidly, so as to keep pace with the more rapid brake-pipe reduction.

LAP POSITION.

When the brake-pipe reduction ceases, air continues to flow from the auxiliary reservoir through ports *z* and *r* to the brake cylinder, until the pressure in the chamber R becomes enough less than that of the brake pipe to cause piston 4, and graduating valve 7 to move to the right until the shoulder on the piston stem strikes the left-hand end of slide valve 3. As the friction of piston and graduating valve is much less than that of the slide valve, the difference in pressure which will move the piston and

the graduating valve, will not be sufficient to move all three; consequently, the piston stops in the position shown in Fig. 329. This movement has caused the graduating valve to close port *z*, thus cutting off any further flow of air from the auxiliary reservoir to the brake cylinder. Consequently, no further change in air pressures can occur, and this position is called "Lap," because all ports are *lapped*,—that is, closed.

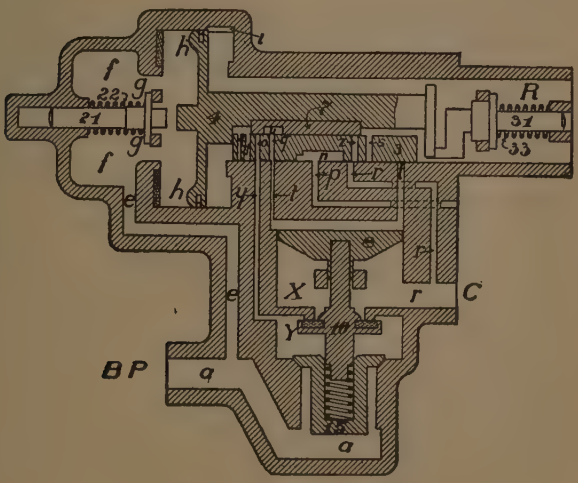


FIG. 329. LAP POSITION

If it is desired to make a heavier application, a further reduction of the brake-pipe pressure is made, and the operation described above repeated, until the auxiliary reservoir and brake cylinder pressures become equal,

after which any further brake-pipe reduction is only a waste of air. About twenty pounds brake-pipe reduction will give this equalization.

RETARDED RELEASE AND CHARGING POSITION.

The K triple valve has two release positions, full-release and retarded-release. Which one its parts will move to when the train brakes are released, depends upon how the brake-pipe pressure is increased; if slowly, it will be full release, and if quickly and considerably, it will be retarded-release. It is well known that in a freight train, when the engineer releases the brakes, that the rapidity with which the brake-pipe pressure increases on any car depends on the position of the car in the train. Those cars towards the front, receiving the air first will have their brake-pipe pressure raised more rapidly than those in the rear. With the old standard apparatus, this is due to two things: (1) the friction in the brake pipe; (2) the fact that the auxiliary reservoirs in the front at once begin to recharge, thus tending to reduce the pressure head by absorbing a quantity of air, and holding back the flow from front to rear of the train. The retarded-release feature of this new triple valve overcomes the second point mentioned, taking advantage of the first while doing so. The friction of the brake pipe causes the pressure in chamber *h* to build up more rapidly on triple valves towards the front than those in the rear. As soon as its pressure is enough greater than the auxiliary-reservoir pressure, remaining in chamber R after the application above described, to overcome the friction of piston, graduating valve, and slide valve, all three are moved toward the right until the piston stem strikes the retarding-device stem, 31.

The latter is held in position by the retarding-device spring, 33. If the rate of increase of the brake-pipe pressure is small, as, for example, when the car is near the rear of the train, the triple valve parts will remain in this position, as shown in Fig. 326, the brakes will release and the auxiliary reservoirs recharge as described under

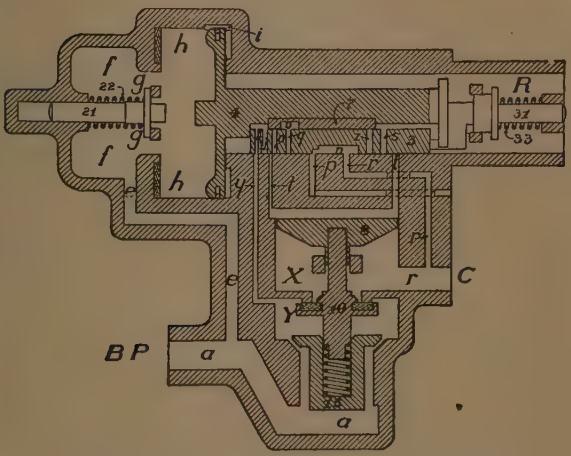


FIG. 330. RETARDED-RELEASE POSITION

"Full Release and Charging." If, however, the triple valve is near the head of the train, and the brake-pipe pressure builds up more rapidly than the auxiliary reservoir can recharge, the excessive pressure in chamber *h* will cause the piston to compress retarding-device spring, 33, and move the triple-valve parts to the position shown in Fig. 330.

Exhaust cavity *n* in the slide valve now connects port *r* leading to the brake cylinder, with port *p* to the atmosphere, and the brake will release; but as the small extension of cavity *n* (see Fig. 325) is over port *p*, discharge of air from the brake cylinder to the atmosphere is quite slow. In this way the brakes on the front end of the train require a longer time to release than those on the rear. This feature is called the "Retarded Release," and although the triple valves near the locomotive commence to release before those in the rear, as in the case with the H-triple valve, yet the exhaust of brake-cylinder pressure in retarded-release position is sufficiently slow to allow the rear brakes to release first. This permits of releasing the brakes on very long trains at low speeds without danger of a severe shock or break in two.

At the same time, the back of the piston is in contact with the end of the slide-valve bush and, as these two surfaces are ground to an accurate fit, their contact effectually cuts off communication between chambers *h* and R through feed groove *i*, preventing air from feeding through from the brake pipe to the auxiliary reservoir by this path. Also, port *l* in the slide valve registers with port *y* in the slide valve seat, and pressure in chamber Y can flow through ports *y* and *l* to the chamber R and the auxiliary reservoir. Chamber Y is supplied with air under these circumstances by the check valve 15 raising and allowing brake-pipe air to flow past it. The area of port *l* is about half that of feed groove *i*, so that the rate that the auxiliary reservoir will recharge is much less than when the triple valve is in the full-release position.

As the auxiliary-reservoir pressure rises, and the pressures on the two sides of piston 4 become nearly equal, retarding-device spring 31 forces the piston, slide valve,

graduating valve, and retarding device stem back to the full release position shown in Fig. 326, when the remainder of the release and recharging will take place as described above under "Full Release and Charging."

These features of the new valve are always available, even when mixed in trains with the old standard, the beneficial results being in proportion to the number of new valves present.

EMERGENCY POSITION.

Emergency Position is the same with the K triple valve as with the H type. Quick action is caused by a sudden and considerable reduction in brake-pipe pressure, no matter how caused. This fall in brake-pipe pressure causes the difference in pressures on the two sides of piston 4 to increase very rapidly, so that the friction of the piston, slide valve and graduating valve is quickly and greatly overcome, and they move to the left with such force that when the piston strikes the graduating stem, it compresses graduating spring 22, forcing back the stem and spring, until the piston seats firmly against the gasket 23, as shown in Fig. 331. The movement of the slide valve opens port *t* in the slide-valve seat, and allows auxiliary reservoir pressure to flow to the top of emergency piston 8, forcing the latter downward and opening emergency valve 10. The pressure in chamber Y, being instantly relieved, allows brake-pipe air to raise the check valve 15 and flow rapidly through chambers Y and X to the brake cylinder, until brake-cylinder, and brake-pipe pressures equalize, when both check valve and emergency valve are forced to their seats by the spring in the former, preventing the air in the cylinders from escaping back into the

brake pipe again. At the same time port *s* in the slide valve registers with port *r* in the slide-valve seat, and allows auxiliary-reservoir pressure to flow to the brake cylinder. But the size of ports *s* and *r* is such that very little air gets through them before the brake pipe has stopped venting into the brake cylinder. This sudden discharge of brake-pipe air into the brake cylinder has the same effect on the next triple valve as would be caused

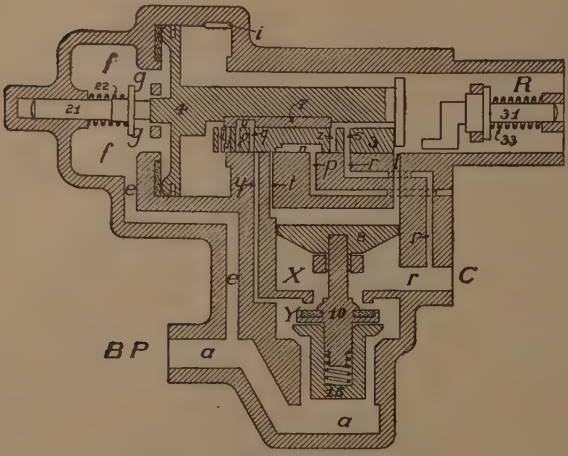


FIG. 331. EMERGENCY POSITION

by a similar discharge of brake-pipe air to the atmosphere. In this way each triple valve applies the next, thus giving the quick and full application of all brakes, made heavier than full service application through the greater amount of brake-pipe air admitted to the brake cylinders.

The rapidity with which the brakes apply throughout the train is so much increased, that in a 50-car train it requires less than three seconds; the brake-cylinder pressure is also increased approximately twenty per cent.

The release after an emergency is effected in exactly the same manner as after a service application, but requires a longer time, owing to the higher brake-cylinder pressures and lower brake-pipe pressures.

To change a standard type H triple valve to the type K, it is necessary to add the retarded-release feature, and to make the necessary changes in the controlling valves, body, and check-valve case.

MANIPULATION.

No special instructions are required by the engineers to handle trains partially, or wholly fitted with the K triple valve. The automatic brake valve should be handled as good practice requires with the H triple valve. Some of the most important details are as follows:

Make the terminal brake tests, and check the results indicated by noting how well the brakes hold in the first running application, and be governed accordingly in subsequent applications.

Before attempting to release have an ample excess pressure for the length of train, and in releasing leave the handle of the automatic brake valve in release position until the rear brakes have had time to release.

As return to running position will cause triple valves in retarded-release position to change to full-release position, the brake-valve handle should not be moved from release too soon. However, with short trains the usual early return to running position will prevent unnecessary retardation of release.

QUESTIONS

1019. What are the principal advantages possessed by the Type "K Triple Valve over the older Types"?

1020. Describe the Quick service feature.

1021. How is this feature produced?

1022. What conditions are secured by the Retarded release feature?

1023. How are the auxiliary reservoirs uniformly recharged throughout the train?

1024. How many sizes of the K valve are at present made?

1025. How may the K-2 valve be distinguished from the K-1?

1026. Mention the principal disadvantages attending a service application with the ordinary quick action triple valve.

1027. Are these conditions present with the K Triple Valve?

1028. Describe briefly full service position.

1029. What conditions are present with lap position?

1030. How are the two release positions of the K Triple Valve designated?

1031. What conditions control the position of full release?

1032. How is retarded release accomplished?

1033. Is there any difference in emergency position, whether with the K Triple Valve, or with the H Type?

1034. What length of time is required for an application throughout a train of 50 cars with the K Triple Valve?

1035. What changes are necessary to convert a type H Triple Valve to Type K?

1036. What are three important rules to be observed by engineers in the handling of trains partially, or wholly equipped with the K Triple Valve?

TYPE L TRIPLE VALVE.

This triple valve has the usual brake-pipe auxiliary reservoir, and brake-cylinder connections, also an additional connection for a supplementary reservoir. Fig. 348 shows a view of the type L triple valve, with the safety valve in place. In order that trains may be controlled easily and smoothly when running at either high or low speeds, and that stops may be made quickly and with the least liability of wheel sliding, the brake apparatus must provide the following essential features of operation:

A small brake-pipe reduction must give a moderate brake-cylinder pressure and a moderate but uniform retardation on the train as a whole.

It must be possible to make a heavy service reduction quickly, but without liability of quick action.

It must be possible to graduate the release as well as the application of the brakes.

To insure the ability to obtain brake applications in rapid succession, and to full power, a quick recharging of the auxiliary reservoirs is necessary. This feature also enables the engineer to handle long trains in heavy grade work with a much greater factor of safety than heretofore, and eliminates the need for retaining valves.

For high-speed trains, a high brake-cylinder pressure available for emergency applications is imperative, in order to provide a maximum braking power, when the shortest possible stop is required to save life or to avoid sudden danger.

The Westinghouse Air Brake Co. claim that they have met the above requirements by the development of the type L triple valve. This triple valve is of the quick-action, automatic, "pipeless" type, and is intended for use only in high-speed passenger service. The L valve

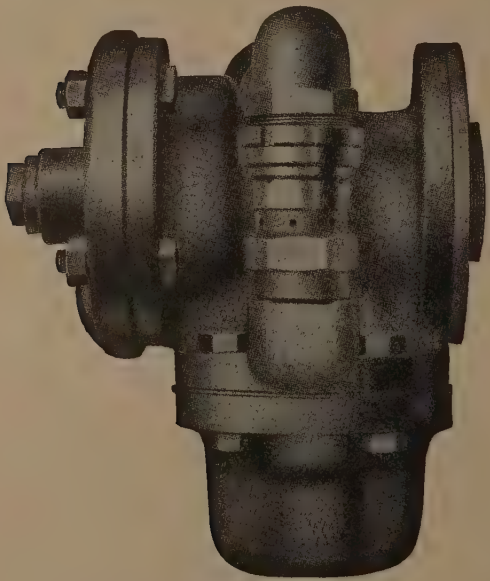


FIG. 348. THE TYPE L TRIPLE VALVE

forms a part of the LN Passenger Car Equipment, which is designed throughout to meet the service conditions outlined above. Being of the quick action type it possesses the following important features:

1st. Quick Recharge (of auxiliary reservoirs), by which a rapid recharging of the brake system is secured, thus making it possible to obtain full braking power immediately after a release has been made and permitting as many applications and releases in quick succession as may be desired, without materially depleting the system.

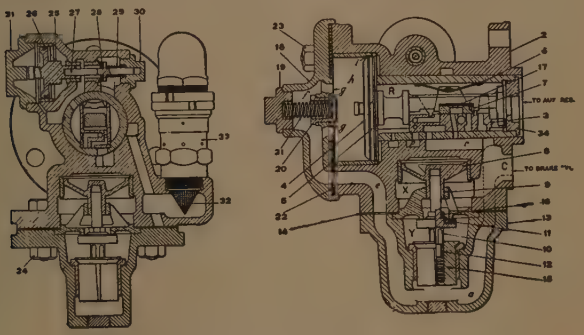


FIG. 349. THE TYPE L TRIPLE VALVE

2nd. Quick Service, by which a very quick serial *service* action of the brakes throughout the train is secured, similar to that in emergency applications, but less in degree. This makes certain the prompt and uniform application of all the brakes in the train, correspondingly increasing the rapidity and effectiveness of any given brake-pipe reduction, and thereby practically eliminating the need for the harsher emergency application, except in cases of actual danger.

3rd. Graduated Release, which permits of partially or entirely releasing the brakes on the entire train at will.

4th. High Emergency Cylinder Pressure, which

greatly increases the available braking power in emergency applications over the maximum obtainable with a full service reduction. With this, as with all quick-action triple valves, a portion of the air contained in the brake pipe is vented to the brake cylinder in emergency applications, thus providing for the quick serial operation of the brakes in the usual way. This, in itself increases the brake cylinder pressure thus obtained, considerably above the maximum pressure, possible in ordinary service applications.

The high emergency pressure feature referred to still further increases this emergency pressure, and the high cylinder pressure thus obtained, is retained without reduction, until released.

This is accomplished by the use of a supplementary reservoir in addition to the ordinary auxiliary reservoir. The supplementary reservoir is approximately double the size of the auxiliary reservoirs. Its function is to assist in obtaining the graduated release of the brakes, and the high emergency cylinder pressure, and the way in which this is accomplished will be explained later on. This feature makes it possible to use the equipment as a high speed brake, when carrying 90 lbs. brake pipe pressure, and obtain better results than when using 110 lbs. pressure with the old standard equipment in steam road service. Fig. 349 shows a vertical cross section of the valve, and the names of its various parts are as follows:

2, Valve Body; 3, Slide Valve; 4, Piston; 5, Piston Ring; 6, Slide Valve Spring; 7, Graduating Valve; 8, Emergency-Valve Piston; 9, Emergency-Valve Seat; 10, Emergency-Valve; 11, Rubber Seat for Emergency-Valve; 12, Check-Valve Spring; 13, Check-Valve Case; 14, Check-Valve Case Gasket; 15, Check Valve; 16,

Emergency Valve Nut; 17, Graduating-Valve Spring; 18, Cylinder Cap; 19, Graduating-Spring Nut; 20, Graduating Sleeve; 21, Graduating Spring; 22, Cylinder Cap Gas-

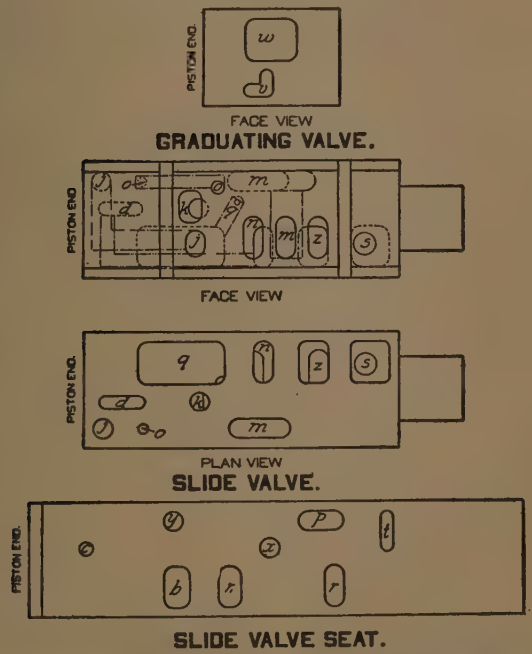


FIG. 350. GRADUATING VALVE, SLIDE VALVE, AND SLIDE-VALVE SEAT. TYPE L TRIPLE VALVE

ket; 23, Bolt and Nut for Cylinder Cap; 24, Bolt and Nut for Check-Valve Case; 25, By-Pass Piston; 26, By-Pass Piston Ring; 27, By-Pass-Valve; 28, By-Pass-Valve

Seat; 29, By-Pass-Valve Spring; 30, By-Pass Valve Cap; 31, By-Pass-Piston Cap; 32, Strainer; 33, E-7 Safety Valve.

Fig. 350 illustrates the actual arrangement of ports, and cavities, in the graduating valve, slide valve, and slide valve seat, of the type L triple valve. Owing to the impossibility of showing all of the ports and con-

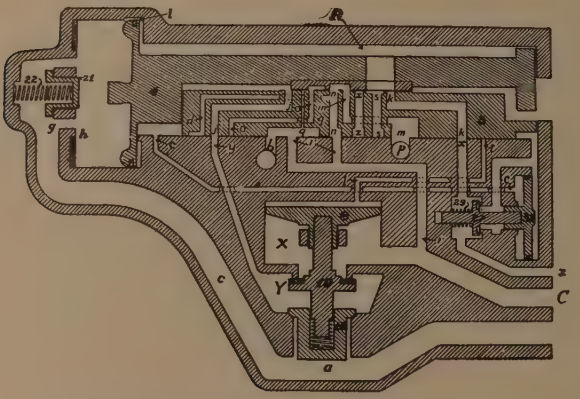


FIG. 351. FULL RELEASE AND CHARGING POSITION

necting passageways in any single illustration, figures 352, 353, 354, 355 and 356, are presented, and each shows in a diagrammatic way, the relations of the various parts to each other, for the different positions of the triple-valve piston.

The actual proportions and mechanical construction of the parts have been disregarded, in order to make the connections, and operation more intelligible to the student. The letters designating the ports and passages appear-

ing on Figures 349 to 356 inclusive, correspond throughout, but the reference numbers on Fig. 349 do not exactly correspond with those on the diagrammatic views. The various connections shown in Fig. 349, and the ports in Fig. 350 will, however, be made clear, by comparison with the diagrammatic views shown in Figures 351 to 356. Referring to Fig. 350, it will be noticed that the

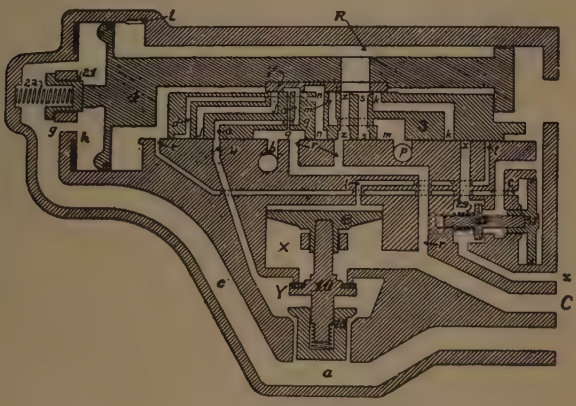


FIG. 352 QUICK-SERVICE POSITION

ports in the plan view of the slide valve seat are as follows: r leads to the brake cylinder; t, to the top of the emergency piston; p, to exhaust; x, to the supplementary reservoir; y, to the check valve case and chamber Y; b, to the safety valve, and c, to the space behind the by-pass piston.

The registration of the parts is most readily followed, and understood, by reference to, and comparison with

the diagrammatic drawings, Figures 351 to 356, in which the connections to the triple valve are as follows:

a—Brake Pipe.
x—Supplementary Reservoir.
C—Brake Cylinder.
p—Exhaust.
b—Safety Valve.
R—Auxiliary Reservoir.

OPERATION OF THE TYPE L TRIPLE VALVE.

CHARGING.

Referring to Figures 349 and 351, air from the brake pipe enters the triple valve through the passages a, e, g, and h, to the face of the triple valve piston (which is then forced to release position as shown), thence through the feed groove *i* to chamber R and auxiliary reservoir. Brake-pipe air in passage *a* also raises the check valve 15, and entering chamber Y flows thence through the ports *y* and *j* into chamber R and the auxiliary reservoir. This check valve then prevents any back flow of air from the auxiliary reservoir to the brake pipe. At the same time, port *k* registers with port *x* and the air in chamber R also flows through these ports into the supplementary reservoir. Both the auxiliary and supplementary reservoirs are thus charged at the same time and to the same pressure from the brake pipe through the two different channels already mentioned. When in this position, air from the brake cylinder, entering the triple valve at C, flows through passage *r*, port *n*, large cavity W (Fig. 350), in graduating valve, and ports *m*, and *p*, to the atmosphere, thus releasing the brakes.

SERVICE APPLICATION.

The ports of the triple valve being in release, and charging as shown in Fig. 351, a service reduction in brake-pipe pressure, reduces the pressure in chamber *h*, and on the face of the triple valve piston, below that in the auxiliary reservoir on the opposite side of the piston.

The higher auxiliary reservoir pressure therefore forces the piston in the direction of the lower brake-pipe pressure, carrying with it the attached graduating valve. The first movement of the piston closes the ports *j*, *m* and *k*, thus shutting off communication between the brake pipe, and the auxiliary and supplementary reservoirs, and closing the exhaust passage from the brake cylinder to the atmosphere. The same movement opens port *z* and connects ports *q* and *o*, in the main slide valve through the small cavity *v* in Fig. 350 in the graduating valve. The spider or lugs on the end of the piston stem, then engage the end of the main slide valve, which is carried along with the piston, and graduating valve, as the reduction continues. This brings the parts into quick service position shown in Fig. 352.

Service port *z* in the slide valve, registers with brake cylinder port *r*, in the seat, thus allowing the air in the auxiliary reservoir to flow to the brake cylinder, and apply the brakes. At the same time the quick service ports, *o* and *q*, and the small cavity *v*, in the graduating valve, connect passage *y*, leading from chamber Y in the check valve case with passage *r* leading to the brake cylinder. This allows air from the brake pipe to lift the check valve, and flow through the above mentioned ports to the brake cylinder. This constitutes the quick service action of the triple valve, in that it causes a slight, but

definite reduction in brake pipe pressure locally, at each valve. The effect of a reduction in brake-pipe pressure, made at the brake valve, is thus quickly and uniformly transmitted from car to car throughout the train. The amount of air vented from the brake pipe to the quick service ports is not great for two reasons; first, because the ports and the passage ways are small; second, because in the movement of the slide valve 3 to full

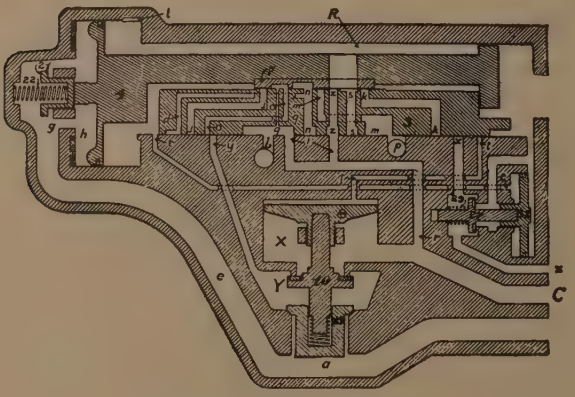


FIG. 353. FULL-SERVICE POSITION

service position, the quick service port y is restricted as it approaches this position and completely closed just before service port x is fully open, as shown in Fig. 353.

The amount of opening given the service port in any case, depends upon the rate of reduction in brake pipe pressure as compared with that of the auxiliary reservoir.

If the former is at first rapid, as compared with the

latter, which would be the case with short trains, the higher auxiliary pressure moves the piston at once to Full-Service Position, Fig. 353, thus automatically cutting out the quick-service feature where it is not needed. When in Full-Service Position, Fig. 353, the service port *z* is fully open, and the quick-service port *o* is closed. This stops the flow of air from the brake pipe to the cylinder and the quick-service action ceases. As shown in the cut, the graduating spring is compressed slightly when the piston is in full service position. In any case where the brake pipe reduction is so rapid, that the quick service feature is of no advantage, the difference of pressure on the two sides of the triple valve piston becomes at the same time sufficient to compress the graduating spring, and automatically close the quick service port as explained above. But if the brake pipe reduction is less rapid, or slow, as in the case of long trains, or moderate service reductions, a partial opening only of the service port is sufficient to preserve a balance between the pressure on the two sides of the triple valve piston. The service port connecting the auxiliary reservoir to the brake cylinder, is much larger than the quick-service port connecting the brake pipe to the brake cylinder. This serves to effectually prevent an emergency application, when only a service application is desired. It also guards against the brake-pipe reduction being continued, due to the quick-service port remaining open, after the reduction has been stopped at the brake valve.

During the time the slide valve 3 remains in Quick or Full-Service Positions, as shown in Figs. 352 and 353, the cavity *q* connects the brake-cylinder port *r* with port *b*, leading to the safety valve. This safety valve, known as the E-7 (see Figures 348 and 349), is ordina-

rily set for 62 lbs. In an emergency application, however, the safety valve is entirely cut off from the cylinder, as explained under the heading "Emergency."

LAP.

After a sufficient brake-pipe reduction has been made, the brake-valve handle is lapped, and further escape of air from the brake pipe is prevented. When the flow

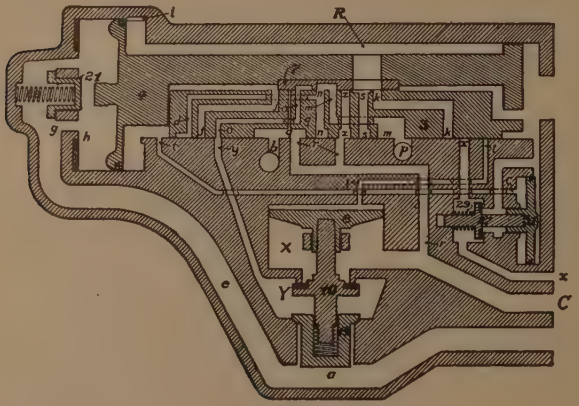


FIG. 354. SERVICE-LAP POSITION

of air from the auxiliary reservoir to the brake cylinder has reduced the pressure on the reservoir side of the triple-valve piston slightly below that remaining on the brake-pipe side, the pressure in the brake pipe, assisted by the graduating spring, will move the piston, and graduating valve to service-lap position, shown in Fig. 354. In this position all of the ports are blanked by the grad-

uating valve, and the flow of air to the brake cylinder is stopped. Further movement is prevented by the shoulder of the piston stem striking the end of the slide valve 3, as shown in the cut. The slight difference of pressure which was sufficient to move the piston and small graduating valve is unable to overcome the added resistance of the slide valve, and the parts remain in the position shown.

It should be noted that the slide valve 3 remains in Service Position, a movement of the piston and graduating valve being all that is required to lap the valve. Consequently, when in this position, only a slight reduction in brake-pipe pressure is required to again bring the piston and graduating valve into Service Position. It is evident that the exact position of the main slide valve in Lap Position depends upon whether its previous position was that of quick service (Fig. 352), or full service (Fig. 353). If the former, the lap position assumed would be that of quick-service lap (Fig. 354). If, however, the valve had moved to full service, the position would be that of full-service lap. The main piston being in service-lap position (Fig. 354), the pressure on both sides of it must be equal. If the brake-pipe pressure is increased in order to release the brakes, the higher pressure on that side of the piston causes it to move the graduating and slide valves to the extreme right to release, and recharging position, previously described (see Fig. 351). The air, which was prevented from leaving the supplementary reservoir by the former movement of the slide valve to service position, and which consequently remained at its initial pressure, while the auxiliary reservoir pressure was being reduced, now flows into the auxiliary reservoir and helps to recharge it.

During this operation, as well as while graduating

the release of the brakes, described under the next heading, the pressures on the brake pipe and auxiliary reservoir sides of the triple-valve piston are always in balance. This is important, since it insures an immediate response of the brakes to any reduction, or increase in brake-pipe pressure, irrespective of what operation may have occurred just preceding.

If the brake-valve handle is moved to Running Position and left there, the brake-pipe pressure is fully restored and the piston remains in Release Position; the brakes being thereby fully released and the auxiliary and supplementary reservoirs fully recharged.

GRADUATED RELEASE.

Suppose, however, that after the brakes have been applied, only sufficient air is permitted to flow into the brake pipe to move piston 4, with the slide, and graduating valves, to release position (Fig. 351), and the brake-valve handle is returned to lap. Then the flow of air from the supplementary reservoir, through ports *x* and *k*, to the auxiliary reservoir, continuing after the rise in brake-pipe pressure has ceased, the pressure on the auxiliary reservoir side of the triple-valve piston will be raised slightly higher than that on the brake-pipe side, and cause the piston, and its attached regulating valve, to move to the left, to graduated release position shown in Fig. 355. In this position the brake is only partially released, and a portion of the air pressure originally in the brake cylinder still remains there. In this way, the brake cylinder pressure may be released in a series of steps, or graduations, and the operation is known as grad-

uated release, and may be repeated as desired, until the brake-pipe pressure has been fully restored, and the exhaust of air from the brake cylinder completed. The amount of reduction in the brake cylinder pressure for any given graduation depends upon the amount of air pressure which has been restored in the brake pipe. The recharge of the brakes is similarly proportioned.

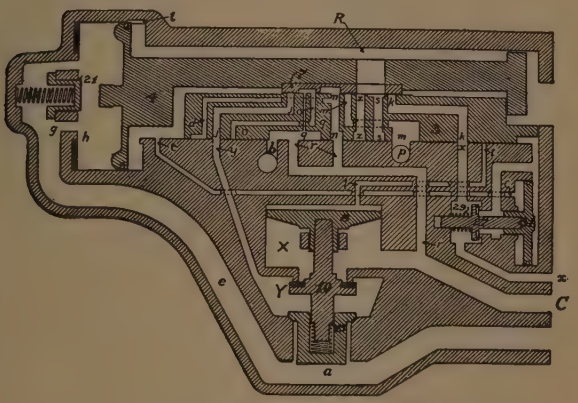


FIG. 355. GRADUATED-RELEASE-LAP POSITION

EMERGENCY.

When the brake-pipe pressure is reduced suddenly, or its reduction continues to be more rapid than that in auxiliary-reservoir pressure, the piston is forced to the extreme left and compresses the graduating spring. The parts are then in Emergency Position, as shown in Fig.

356. In this position air from the auxiliary reservoir enters the brake cylinder passage *r* through the port *s* in the main slide valve, instead of port *z* as in service application. Port *t* in the seat is also uncovered by the end of the main slide valve, thus admitting air from the auxiliary reservoir, through port *t* to the top of the emergency piston.

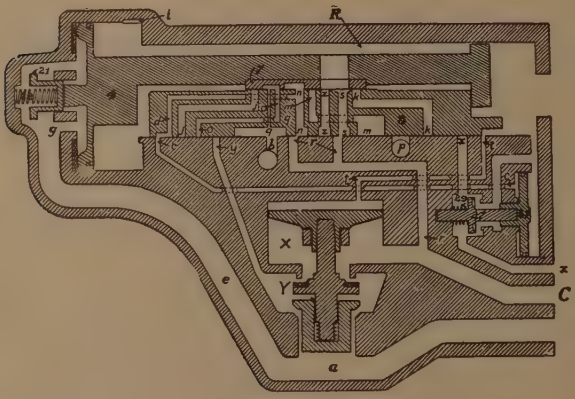


FIG. 356. EMERGENCY POSITION

The air pressure thus admitted to the top of this piston, pushes it down and forces the rubber seated emergency valve from its seat. This allows the brake pipe air in passage *a* to lift the emergency check valve, and flow through chambers *y* and *x* to the brake cylinder *C*, in the ordinary way. At the same time port *d*, in the main slide valve, registers with port *c* in the seat. This allows air from behind the by-pass piston to flow through ports *c*, *d* and *n* to *r*, and the brake cylinder. As there is no pressure

in the brake cylinder at this instant, the by-pass piston, with its attached by-pass valve is forced to the left by the auxiliary reservoir pressure acting against its opposite face. The air contained in the supplementary reservoir then flows past this valve into the passage way leading to the auxiliary reservoir. It thereby adds to the latter, the volume of the supplementary reservoir.

This gives in effect an auxiliary reservoir pressure volume approximately three times the size of the one that supplies air to the brake cylinder in a service application. Air from the supplementary reservoir continues to flow to the auxiliary reservoir until the pressures in the latter, and in the brake cylinder have risen nearly to that remaining in the supplementary reservoir. Communication between the two reservoirs is then closed by the by-pass valve returning to its seat.

This action of the triple valve in the emergency applications permits the pressure in the brake cylinder to rise to within a few pounds of maximum brake-pipe pressure, a much higher pressure being secured in emergency applications than is possible with the standard quick-action triple valve.

Further more it will be noted by reference to Fig. 356 that cavity *q* has traveled past the brake cylinder port *r*, so that the latter is no longer connected to the safety valve *b*. Hence, there is no escape of air from the brake cylinder after an emergency application of the brakes. Not only, therefore, is the emergency pressure considerably higher than that formerly secured by the use of the old standard High-Speed Brake, but it is held without diminution until the brakes are released.

INSTALLATION AND MAINTENANCE.

The triple valve is usually bolted to the pressure head of the brake cylinder, to which all the pipe connections are permanently made. In removing the valve, no pipes need to be disconnected, the loosening of the three bolts which hold it in place being all that is required. Hence, the name "Pipeless," as applied to this valve. Care should be taken in locating the valve to have it free from obstructions which would render inspection or removal difficult. It should be placed as far as possible above the general level of the piping so that no pockets are formed in the latter. If this point does not receive proper attention, trouble may be experienced in cold weather from the freezing of water in the pipes or valve itself. Under ordinary service conditions, the triple valve should be thoroughly cleaned and lubricated once in three months. The proper interval is best determined for each particular case by a careful inspection and trial. Where conditions are severe and the triple valve exposed to extremes of weather, dirt and so on, more frequent inspections will no doubt be found necessary. Where the valve is protected, and not subjected to hard usage the interval may be lengthened. The use of heavy grease or other lubricants which will "gum" and cause the valve to work stiff, or clog the ports, should be avoided. Too light a lubricant or one that does not possess sufficient "body," is not satisfactory, as it will not thoroughly lubricate the parts or last as long as necessary. Special lubricants made for this purpose will give the best results.

Before installing the triple valve all of the piping should be thoroughly hammered and blown out, in order

to loosen and remove all scale and foreign matter. This is especially important in new installations. After the piping is completed all of the joints should be thoroughly tested with soap suds, under pressure, and made air tight. Particular attention should be given to the safety valve and its strainers, in order that no dirt or scale can reach the safety valve seat and prevent it from properly closing. The by-pass piston should also receive attention to insure that it is working freely in its bushing.

Never remove the movable parts of the triple valve while it is on the car. If the valve is not working properly, or needs cleaning and oiling, take it down and replace it by a valve in good condition. All cleaning and oiling should be done at a bench, by a competent man; where the liability of damage to the internal parts of the valve is least. Any attempt to take the triple valve apart while still on the car is almost sure to result in a large percentage of valves being injured by careless handling, or dirt getting inside the pipes, or valve. If repairs are necessary the valves should be sent to the shops, where the facilities for doing the work are best.

The complete LN equipment includes a type L valve triple valve, with safety valve, a supplementary reservoir and a cut-out cock. At times, however, cars equipped with this schedule must be operated in trains with cars having the old standard equipment (P triple valves), as for instance during the transmission period when a change is being made from the old standard to the LN schedule.

During this time the cut-out cock between the triple valve and supplementary reservoir should be closed. The new valves will then work in perfect harmony with the old. In fact, if old and new equipments are to be

in service together for any considerable length of time, the cut-out cock and supplementary reservoir may be omitted entirely, as well as the safety valve, furnished with the triple valve. If the equipment is used with 70 lbs. brake-pipe pressure, no other change is necessary, and only the addition of the ordinary High-Speed Reducing Valve is required for High-Speed Service (110 lbs. brake-pipe pressure). In such cases where the conditions of service demand, there would, of course, be the same necessity for a Pressure-Retaining Valve, as with the Type P Triple Valve.

QUESTIONS

1069. What are the requirements of a brake apparatus?

1070. Wherein does the type L valve differ from the older equipments?

1071. What important feature does the type L valve possess?

1072. In what way is the high emergency pressure feature secured?

1073. What is the function of the supplementary reservoir?

1074. Describe in brief, the process of charging and release?

1075. How is service application accomplished?

1076. How is quick service brought about?

1077. Upon what does the amount of opening given the service port depend?

1078. If the reduction is so rapid that the quick service feature is no advantage, how does the graduating spring act?

1079. What is the result when the brake-pipe reduction is moderate or slow?

1080. Is there any liability of an emergency application occurring when only a service application is desired?

1081. How is this regulated by the L valve?

1082. How is the position of lap accomplished?

1083. What is the function of the graduating valve in lap position?

1084. Upon what does the position of the main slide valve depend in lap position?

1085. How is the position of graduated release regulated by the L valve?

1086. What are the advantages of graduated release?

1087. In what way is emergency position brought about?

1088. How is the volume of air available for use in the brake cylinder increased in case of emergency?

1089. Is it possible to secure a higher pressure in emergency application with this valve than it is with the standard quick action valve?

1090. Is there any escape of air from the brake cylinder after an emergency application with the L valve?

1091. Why is the L valve called a "Pipeless" valve? Describe briefly the proper location of the valve when installed.

1092. How often should it be cleaned and inspected?

1093. What should be the nature of the lubricant used on it?

1094. What should be done with the piping before installing the valve?

1095. Mention the parts that should receive particular attention.

1096. If repairs are necessary, what should be done with the valve?

1097. What does the complete LN equipment include?

1098. Can it be operated in conjunction with the old standard equipment?

1099. What changes are necessary in order to accomplish this?

1100. In case High-Speed Service (110 lbs. brake-pipe pressure) is required, what additions are necessary?

INDEX.

A

Air brake, advantages of in electric railroading..... 1
Amperes per motor.....540
Average speed of interurban electric cars..... 1

B

Brakes—arrangement of brake rigging.....542-543
Dimensions of parts.....544
Mechanism of, on double truck cars.....543
Principles governing action of.....541-545
Various methods of operating.....541-542
Braking data for motor cars.....235-237

C

Catechism on operation of electric locomotives..355-385
A. C. circuit breakers.....373-374
A. C. Trolley 374-375
At end of run.....359
Blowers 382-383
Brakes 379-380
Change from A. C. to D. C.....363-364
Change from D. C. to A. C.....364-365
Change over switches 378-379
Controllers 379
Cutting out motors.....380-381
Double heading 367

Catechism on operation of electric locomotives—Cont.
Failure of air supply....381-382
Fuses 383-385
Operation on A. C. third rail....366-367
Operation on D. C. overhead rail....365-366
Preparation for run....358-359
Raising A. C. trolley....368
Raising D. C. trolley....369
Sanders 385
Standing in A. C. zone....356-357
Standing in D. C. zone....357
Starting trains 372-373
Switching positions 360-363
Temperature of motors....382
Testing control 369-371
Third rail shoes....377-378
Transformers 373
Train failures, fire....371-372
Unit switch groups....376-377
When leaving a terminal....360
Christensen Air Brake—
Automatic governor 173-176
Brake cylinders 180
Classification of motor compressors....169-170
Diagram of piping....172
Engineer's brake valve....177-180
Engineer's brake valve, rotary type....177-178
Engineer's brake valve, slide valve type....179-180
J. emergency valve 187-195
J. emergency valve, application of....190-191
J. emergency valve, construction of....189-190
J. emergency valve, function of....188
J. emergency valve, operation of....192-193

Christensen Air Brake—Continued.
J. emergency valve, parts of.....192
List of parts for motor and trailer cars.....194-195
Motor compressor, description of.....172-175
O. B. pneumatic governor 181-182, 186
O. B. pneumatic governor, parts of.....186
Piping 181-182
Compressed air in railway work.....491-492
Currents that will fuse wires of different substances.530

D

Dead level, in braking systems.....237-238
Dimensions and resistance of copper wire.....532

E

Electric Brakes 238-244
Basic principle of.....238-239
Price-Darling 242-244
Price-Darling, construction of.....243
Westinghouse 239-242
Westinghouse, construction of.....240-241
Westinghouse, operation of.....241-242
Electric freight locomotive.....512-514
Economy of, compared with steam.....513-514
Electric locomotive 272-342
Air compressor control.....315
Air compressor motor switch.....306-315
Air pump governor, sectional view.....314-315
Bipolar gearless D. C. motor.....277-278
Bus line coupler.....301-303
Bus line coupler socket.....301-302

Electric locomotive—Continued.
Control cut out switch 312-326
Control fuses 311-314
Current limit relay.....310-313
Forced ventilation 276-336
Heating apparatus 281
Main cut out switches.....296-298
Main switches 296-297
Master control apparatus, list of parts.....302
Master controller 302-304
Master controller, main switch.....305-307
Master controller, overhead switch.....305-307
Mechanical construction 276-281
Motor armature 282
Motor control apparatus, parts of.....292-301
Motor control contactor.....293
Motor control grid resistance.....295
Motor control reverser.....294
Motor control rheostats.....295-296
Motor fuse box.....299
Negative train cable.....305-307
Operation of control.....288-292
Overhead contact device.....300-301
Overhead shoe fuse boxes.....300
Rating and capacity.....272-275
Third rail contact shoes.....300
Third rail shoe fuse box.....299-300
Track sander control.....316-317
Track sander electro-pneumatic valve.....317-318
Track sander main switch.....306-316
Track sander operating switches.....316-317
Train cable 307-310
Train cable connection boxes.....310-312

Electric locomotive—Continued.
Train cable coupler plug....309-310
Train cable coupler socket....308-310
Train operation, controller steps....320-322
Train operation, general....318-326
Train operation, path of current....324
Train operation, position of reversers....322
Train operation, reversing direction....324-326
Train operation, sanding the rails....326
Transmission of current....326-327
Trolley system....327
Wiring diagram of four motors....284
Explanation of....283-286
Wiring diagram of locomotive reverser....287
Explanation of....286-287
Electric locomotive of Indiana Union Traction..386-395
Bell and searchlight....394-395
Body framing....393
Brake rigging....388
Brakes....393-394
Controller....392
General dimensions....386
Marker lights....395
Motor....389
Motor armature....388-392
Motor brush holders....392
Motor commutator....391
Motor suspension....388
Steel under frame....392-393
Trolley base, and retrievers....395
Trucks, description and dimensions....386-389
Wiring diagram....392

Electric locomotive of N. Y., N. H. & H. Ry.....326-342
Armature mounted 332
Auxiliaries 340-341
Cab 329
Control system 337-340
Current collection 336
Description of 328-336
Dimensions and performance.....341
Driving quill 333
Equipment 330-335
Frame and trucks.....328-329
Master controller 337-340
Motors 330-331
Pockets in driver for quill fingers.....334-335
Speed recorder 342
Suspension of motors.....332-334
Tests 341-342
Unit switch group.....339
Electric locomotive—new type.....507-511
Advantages claimed for.....507
Flexible coupling 510-511
Plan and elevation.....509
Evolution of the brake shoe.....244-251
Corning type 245
Motor and trailer shoes.....247
Steel back shoe.....248-249, 251

F

Fusing effects of currents.....538

G

General Electric Co.'s air brake.....196-231
Air compressor 198

General Electric Co.'s air brake—Continued.
Air compressor, care and maintenance of..199-202
Air compressor, direction of rotation.....204
Air compressor, list of parts.....201
Air compressor, method of removal.....204-205
Air compressor, valves 202-203
Brake cylinder 212-213
Combined switch and fuse.....208-209
Cut-out, stop and angle cocks.....215
Emergency straight air brake equipment...218-231
general arrangement of.....219-220
list of parts.....219-221
piping connections 221-222
type S. form D.....222
type S. motorman's valve.....222
type S., parts of.....224
type S. parts, positions of.....222-225
Emergency valve, type E. form F.....226-230
parts of 227
operation of 229-230
Exhaust muffler 216-217
General construction 217-218, 231
Governor 205
Governor, inspection and care of.....207-208
Governor, sectional view.....206
Hose couplings 215-216
Motorman's brake valve 209-212
Motorman's brake valve, installation of.....212
Motorman's brake valve, positions of.....209-210
Motorman's brake valve, type S. form B.....211
Motorman's brake valve, type S. form C.....210
Pipe connections 230-231
Reservoirs 213-214

General Electric Co.'s air brake—Continued.
Safety valve and air gauge.....214-215
Straight air brake equipment 196
Straight air brake, piping diagram.....197

H

Head light, enclosed arc, for street railway service 396-399
Adjusting the headlight.....397
Connecting 397
Enclosing globe, reflector, carbons.....398
Installation of system.....396
Trimming the headlight.....398-399
Hints to Motormen.....49-55
Brake pipe rupture..... 51
Control and branch pipe rupture..... 52
Cutting out brakes..... 49
General hints 52-54
Rail sanding 50
Reversing motors 51
Switching cars 49
Unexpected brake application..... 50

I

Interurban railways—increasing profits of.....519-522
Cost of operation.....520
Distribution of labor.....521-522

K

K triple valve 644-665
Characteristics of 644-646
Names of parts.....647-649

K triple valve, vertical cross section of.....648
K 2 triple valve.....649-665
action of explained.....649-652
catechism on 666-667
emergency position 663-665
face view of 650
full release and charging position. 652-653
full service position.....657-658
lap position 658-659
manipulation 665
quick service position.....654-656
retarded release and charging position.....660-663

L

L triple valve 669-688
Catechism on 688-690
Charging position 676
Emergency position 683-685
Face view of 673
Full release and charging position.....674
Graduated release position.....682-683
Installation and care of.....686-688
Main features of.....669-671
Names of parts.....672-674
Operation of 676-688
Quick service position.....675
Service application position.....677-679
Service lap position.....680-682
Supplementary reservoir 672
Vertical cross section.....671
Lightning arresters, aluminum.....463-490
Assembling of filling cones.....482-485
Condenser action 466

Lightning arresters, aluminum—Continued.
Connections and wiring....480-481
Cross section of....467
Daily inspection and repairs....488-490
Design of....468-469
Electrical characteristics of....463-466
Filling tank with oil....486
Film dissolution....466-468
Gap setting....478-480
Horn gaps, clearance....476
Horn gaps, installation of....472-476
Horn gaps, location of....470-477
Horn gaps, method of locking....471
Horn gaps, method of support....474
Installation of discharge alarm....481-482
Installation of tanks....476
Outdoor installation....478
Placing arresters in service....486-488
Testing and preliminary charging....485-486
Three phase arrester for 35,000 volts....474
Three phase arrester for 110,000 volts....475
Transfer device....489
Valve action....463-464
Volt ampere, characteristic curve....465
Lightning arresters for D. C. circuit....461
Lightning arresters for D. C. circuit, dimensions of..462
Lightning arresters, multigap for alternating currents....410-430
A. C. arresters with shunt resistance....446
Advantages of....410-411
Basic principles of....414
Choke coils....430-431
Choke coils for A. C. arresters....454-455

Lightning arresters, multigap for alternating currents—Continued.
Connections of Type G. E., Forms F^1, F^2.....440
Constant current arresters.....428-430
Cumulative effect 416-417
Cylinders and resistance rods.....418
Definition of spark 411
Dimensions of A. C. arresters high voltage..447-453
Dimensions of A. C. arresters low voltage...442-445
Direct current lightning arresters 432-433
Disconnecting switches 429
Disconnecting switches for A. C. arresters..442-445
Distribution of static stress.....412-413
Dynamic arc 413
Forms F^1 and F^2.....424
Fuse auxiliaries 421
Graded shunt resistance 414-415
Ground connections 433-436
Grounded Y and non-grounded neutral systems.419
Hour glass type 431-432
List of shunt resistance arresters up to 5,700 volts 437-439
Low voltage arresters.....427-428, 441
Multiplex connections 420
Oscillogram of discharge 425
Spacing and setting of gaps 422
Voltage, range of.....423
"V," unit for 418-421
3,000 volt arrester 426
Lightning arresters, recent developments of.....400-462
Action of, under dangerous voltage.....405-406
Aluminum and electrolytic type.....403
Car arrester 407

Lightning arresters, recent developments of—Continued.
Connections of 408
General remarks concerning object of.....400-402
General theory of multigap arrester.....404
Horn arrester 402, 458-460
How to fill the arrester.....407
Installing low voltage aluminum arrester..406-407
Operation of 408-409
Station arrester 406

M

Minimum brake distance and clearance of metal part of fuses and switches 539
Maintenance of hand brakes.....257-260
Maintenance of schedule time.....232

N

National A. C. D. C. air brake apparatus.....161-168
Diagram of equipment.....162
Compressor 163-166
Compressor, method of starting.....166-167
Compressor, method of suspension.....167-168
Compressor, partly dismantled.....165
Compressor, type B. B. 2.....164
Type N. oil pneumatic governor.....168
National straight air traction brake.....79-158
A. 2 motor compressor 104-106
single-truck equipment 105
wiring for 134-136
brush gear 92-95
care of commutator.....94
connecting up 86-88

National straight air traction brake—Continued.
A. 4 motor compressor 85-105
D. C. series wound.....99-105
inspection and maintenance 89-99
sectional diagram of.....97-98
suction and discharge valve..... 96
the motor 101-102
wiring diagram 135
Air gauges, installation of 131
Air reservoir 128-129
Air reservoir, installation of.....130
Brake cylinder 124-126
diagram of 125
inspection and maintenance.....127-128
installation of 126
Conductor's valve 154-155
Emergency valve 149-153
installation and maintenance of.....153-154
mounted on bracket.....152
mounted on brake cylinder.....151
sectional diagram 150
Energy consumed in braking.....160-161
Fuse block 136-137
General arrangement of 79-80, 83
Instructions to motorman.....154-158
Making up trailers 158
Motorman's valve 137-146
installation of 145
lap position 144
maintenance of 146
parts of 140
positions of operating handle.....142
quick release or emergency.....143-145

National straight air traction brake—Continued.
Motorman's valve, running and service positions.143
sectional view 141
slow service position.....144
Piping 131-134
Piping diagram 132
Piston travel 159-160
Pneumatic governor 106-113
installation of 113-114, 122
operation of 114-122
view showing parts.....123
Type C. sander valve.....148
Type C. C. 3 compressor.....147-148
New air brake equipments for steam railroads..545-546
Condensed description of latest devices.....547-589
New York Air Brake Co.'s B 2 equipment.....547-564
Acceleration valve 571-573
Acceleration valve, sectional view.....572
Acceleration valve, names of parts.....573
Acceleration valve, slide valve.....573
B 2 brake valve.....573-564
Automatic release and straight air application 559-560
Emergency position 562-563
Face of slide valve.....553
Graduating positions 561-562
Lap position 560-561
Release position 557
Running position 558-560
Sectional views 554-555
B 2 H. P. equipment.....549-550
B 2 H. S. equipment.....548-549
B 2 S. equipment.....548

N. Y. Air Brake Co.'s B 2 equipment—Continued.
B 2 S. switch engine equipment....564
Catechism on 582-584
Characteristics of 547-548
Duplex pressure controller 565-570
Duplex pressure cut out cock....569-570
Duplex pressure regulating valve....565-568
Duplex pressure supply valve....556
General instructions for operating....550-552
High speed controller 577-581
High speed controller, action of....578-579
High speed controller, sectional view....578
Quick release valve for switch engines....579-581
Straight air reducing valve....574-576
Straight air reducing valve, names of parts..575-576
Straight air reducing valve, purpose of....574
Straight air reducing valve, sectional view....575

O

Operation of brakes 252-260
Failure of hand brakes....254-255
Lengthened brake chains....255-256
What to do in emergency case....256-257

P

Power plant auxiliaries, centralized control of...516-519
Power required to skid car wheels....234

S

Storage air brakes....260-261

T

Treatment for electrical shock....524-528
Rules to be observed in....526-528

Trolley wire 493-506
Characteristics of 494
Correct method of testing.....496-501
Efficiency of 493-497
General method of suspension.....495
Influence of cuprous oxide.....500-502
Length of in use at present.....493
Method of manufacture.....502-503
Requirements of for efficient service.....495-496
Results of tests of various grades.....498-499
Turn-tables, electrically operated.....343-354
Advantages of 343-345, 350
Methods of current transmission.....352-354
Turntable with steam donkey.....344-347
Type of motor required.....349-351

W

Westinghouse A. A. M. brake equipment.....2-48
Alarm whistle 32
Arrangement of apparatus.....20-24
Auxiliary reservoir 39-40
Brake valve 32-35
Catechism on 55-77
Combined strainer and check valve.....37-39
Conductor's valve 35-36, 50
Control pipe 29-32
Diagram showing arrangement..... 5
Electric pump governor, adjustment of....23-24, 27
Feed valve, location of 28-29
Inspection and maintenance.....40-42
Installation of wiring 24-26, 28
Leading characteristics of.....2-3

Westinghouse A. A. M. brake equipment—Continued.
Location of air compressor....20
Main reservoirs, why two are used....21-22
M. triple valve, charging position....13
description of....7-9, 12
emergency position....19
graduated release position....18
lap position....16-17
operation of....13-19
service application position....14-15
Operating parts of....4-7
Operation of equipment....42-44
Practical train tests....45-48
Safety valve....28
Snap switches, where placed....24, 126
Trailer car equipment....20
Where to locate compressor switches....28
Westinghouse E. T. locomotive brake equipment. 585-689
Advantages over older systems....585-586
Arrangement of apparatus....591-594
Automatic operation....602-612
Automatic operation automatic release....602
Automatic operation double heading....610-613
Automatic operation emergency....607-608
Automatic operation emergency lap....609-610
Automatic operation release position....611
Automatic operation service application....602-604
Automatic operation service lap....604-607
Catechism....638-642
Dead engine feature....643-644
Distributing valve....594-597, 613
Distributing valve, diagram of....596
Distributing valve, independent application. 597-599

Westinghouse E. T. locomotive brake equipment—Cont.
Distributing valve, independent release.....600-602
Distributing valve, independent lap.....601
Distributing valve, release position.....598
Feed valve 630-634
Feed valve, diagram of, closed.....633
Feed valve, diagram of, open.....633
Feed valve, function of.....630-633
Feed valve, methods of adjustment.....634
Feed valve, names of parts.....634
General instructions for operating.....586-589
Graduating valve—equalizing slide valve.....612
Independent brake valve.....625-629
Independent brake valve, action of.....625-628
Independent brake valve, interior views....627-629
Independent brake valve. lap and release positions 628
Independent brake valve, service position.....628
Parts of E. T. equipment.....589-591
Pump governor 635-638
Pump governor, description of.....637
Reducing valve 635
Safety valve 614-616
Type H automatic brake valve.....616-619
diagrammatic view 618
emergency position 624
holding position 623
lap position 622
location of 624-625
names of parts 625
release position 623
rotary valve seat 618
running position 621

Westinghouse E. T. locomotive brake equipment—Cont.
Type H automatic brake valve, service position.621-622
side sectional view 620
top view of 619-620
Westinghouse-Galton Friction Curves.....233
Westinghouse Straight Air Brake Equipment...262-266
Diagram of schedule S. M. 1.....263
Parts of schedule S. M. 1..... 262-265
Schedule S. M. 2.....265-266
Westinghouse Straight Air S. M. E. Equipment..266-271
Air compressor, S. M. E.....271
Brake cylinder 270
Brake valve, S. M. E.....269
Diagram of 266
Emergency valve, S. M. E.....269
For two-car train operation.....267
With emergency feature 267-271
Why steam roads adopted electricity.....514-515
Wire and cables, carrying capacities of.....531
Wiring constants 533-537
Wiring formulæ 529-530
Wooden ties and preservation of.....522-523